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EARTH CURRENT SURVEYS FOR NEW PIPE LINES¹

BY E. E. MINOR²

In the selection of a route for a new feeder main, geographical and profile studies may not present all of the engineering aspects of the problem which need consideration. Stray currents, which are often overlooked in the location of a new pipe line, may be the governing factor in the eventual life of the pipe. Therefore, they are decidedly worth studying before the pipe line location is definitely decided upon. If hazardous conditions are found on one route, it may be possible to avoid them on another, or as often happens, the stray current hazards can be materially reduced or eliminated before the pipe is laid. An accurate knowledge of all phases of the stray current problem as it affects the new pipe line is also of vital importance in the design and construction of the line, because mitigative measures can be applied much more easily and cheaply as the line is laid, than they can after the job is once completed.

In developing a water supply for New Haven we have planned a 48-inch pipe line coming into New Haven on the east. This roughly parallels an interurban electric railway for about 5 miles. The soil is for the most part sandy and of relatively high electrical resistivity. Approaching the city we pass under another electric interurban line with the soil changing to low salt water marshes of low resistance,

¹ Presented before the New York Section meeting, December 28, 1928.

² Chief Engineer, New Haven Water Company, New Haven, Conn.

through which our line would pass for about 2,000 feet and then under a broad tidal estuary, 1,500 feet in width, to a sandy high resistance soil in the city.

Earth current surveys were made by Albert F. Ganz, Inc., of New York City under the direction of its engineer, C. F. Meyerherm. The results were surprising and we have included the report in this paper, thinking it would be of interest, in a general way, to members of the Association. Here are soil resistances ranging from 420 to 126,000 ohm-centimeters; voltage gradients running from negligible values up to magnitudes of 282 volts per thousand feet. Needless to say, much improvement will be made in these conditions before our pipe is laid. We believe it shows, however, the value of investigating these conditions before installing thousands of dollars in pipe line which would be immediately subject to depreciation from causes which could be partly eliminated and partly guarded against. The report follows.

REPORT ON ELECTROLYSIS SURVEY

In accordance with our understanding with you we have made a series of electrolysis tests at characteristic points along the route of the proposed North Branford-New Haven water supply main and we give you herewith our report on the results.

The object of the present investigation was to determine: (a) existing stray current gradients in the earth in the territory through which the proposed pipe line will pass; (b) the electrical resistivity of the soil at characteristic points along the route; and (c) the most desirable locations for any electrically insulating joints which might have to be installed in this pipe line in order to minimize stray current electrolysis action on this pipe line.

We understand the proposed water main will be a 48-inch cast iron line laid along Foxon Road, and therefore approximately parallel to the New Haven and Shore Line Railway tracks from North Branford to the junction of Foxon Road and Essex Street, Fair Haven. At the latter point the pipe line will turn into Essex Street which it will follow to Quinnipiac Avenue. At Essex Street and Quinnipiac Avenue, the new line will reduce to 42-inch and then continue by private right of way through the salt meadows bordering the east bank of the Quinnipiac River, crossing the river to Peck Street, New Haven. Along Peck Street, the new North Branford supply line will continue west to Blatchley Avenue where it will connect to a new 24-inch cross main which will run from Grand Avenue through Blatchley Avenue and Willow Street to Whitney Avenue.

Measurements of soil resistivity and of voltage gradients existing in the earth both parallel and at right angles to the proposed pipe line were made at the following characteristic locations:

1. In the salt marsh just east of the New York, New Haven and Hartford R. R. embankment (Shore Line Division).

TABLE 1

Earth gradient and soil resistivity measurements along route of proposed North Branford-New Haven water supply main, June 20-21, 1928

LOCATION AND CHARACTER OF SOIL	AVERAGE SOIL RE- SISTIVITY <i>ohm-cen- timeters</i>	EARTH GRADIENT VOLTS PER THOUSAND FEET			
		Parallel to pipe		Transverse	
		Maximum	Average	Maximum	Average
300 feet west of Quinnipiac Avenue at Essex Street: Black meadow mud.....	420				
Essex Street, just west of Quinnipiac Avenue: Red sand and loam.....	122,400			2.3S 0.4N	0.83S 0.06N
Red sand and loam (60 minutes test).....		10.0E 32.0W	3.4E 1.1W		
Essex Street (north side) just east of Quinnipiac Avenue: Red sand and loam.....	126,300	1.2SW	0.83SW	2.4NW 10.0SE	0.77NW 0.98SE
Essex Street (north side) 500 feet Northeast of Quinnipiac Avenue: Red sand and loam.....	7,520				
Foxon Road, opposite Capella's Gas Station south of Shore Line tracks: Red sand and loam.....	70,600	3.0SW 0.4NE	0.77SW 0.03NE	6.8SE	2.0SE
Foxon Road, 75 feet east of Shore Line Pole No. 176 (L. H. Goodrich property) north of tracks: Red clay and sand.....	58,800	1.0E	0.61E	1.0S 200N	0.05S 8.8N
Red clay and sand (265 minutes test).....				62.0S 282N	Neg. 23.0N

2. In the high ground just west of Quinnipiac Ave.
3. On Essex Street in the high ground just east of Quinnipiac Ave.
4. On Essex Street approximately 500 feet east of Quinnipiac Ave.

5. Near the junction of Essex Street and Foxon Road.

6. At Foxon near the L. H. Goodrich property.

Soil resistivity tests were made at all of the above locations with the earth-current meter and the regular four terminal earth-current meter electrode inserted in a 2½-inch hole drilled in the earth to approximate pipe depth. Gradient tests were made at four locations with a Rawson voltmeter and a pair of non-polarizable electrodes inserted in the earth at points 100 feet apart except at location No. 6 where the spacing had to be reduced to 50 feet.

The results of the tests are given in table 1.

It will be noted that in the salt marsh just east of the New York, New Haven and Hartford Shore Line Division railroad embankment the soil resistivity is exceptionally low averaging only 420 ohm-centimeters. In the

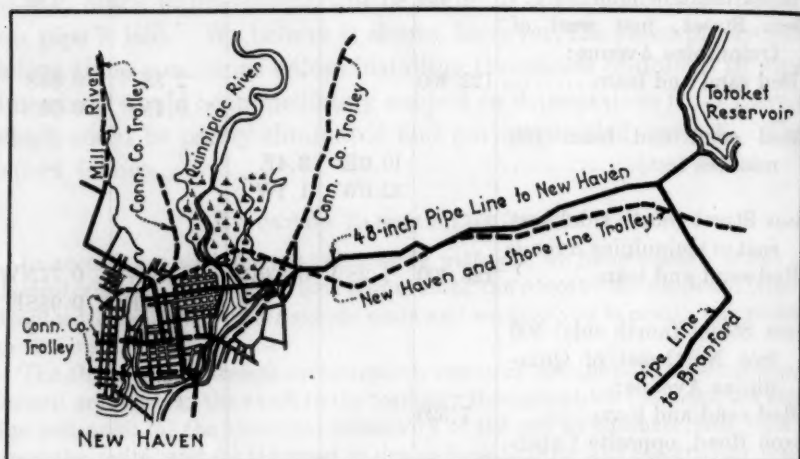


FIG. 1. NEW HAVEN WATER COMPANY. DIAGRAM SHOWING LOCATION OF PIPE LINE AND ELECTRIC RAILWAYS

slightly higher ground near Quinnipiac Avenue, the soil resistivity was extremely high, averaging 122,400 ohm-centimeters, west of Quinnipiac Avenue, and 126,300 ohm-centimeters on Essex Street just east of Quinnipiac Ave. About 300 or 400 feet further east, Essex Street runs through salt marsh and in this locality the soil resistivity averaged 7,520 ohm-centimeters. At Foxon Road and Essex Street, where the new pipe will run parallel and close to the New Haven and Shore Line tracks the soil resistivity averaged 70,600 ohm-centimeters while in the town of Foxon it averaged 58,000 ohm-centimeters.

The tests of voltage gradient in earth showed that in the vicinity of Quinnipiac Avenue there is an extremely high voltage gradient in earth at right angles to the Quinnipiac Avenue trolley tracks of The Connecticut Company, and therefore practically in line with the proposed pipe line. The maximum gradient along the line noted at the locations either side of Quinnipiac Avenue ranged from 1.2 to 32 volts per thousand feet, while the maximum gradient at right angles to the line ranged from 0.4 to 10 volts per thousand feet.

At Foxon Road and Essex Street the gradients were not as high as they were near Quinnipiac Avenue, but yet the maximum values ranged from 3.0 volts per thousand feet parallel to the line to 6.8 volts at right angles. At Foxon the maximum gradient parallel to the line was 1.0 volt, while the maximum gradient at right angles to the line exceeded 200 volts per thousand feet in the field north of Foxon Road near the L. H. Goodrich property. This occurred with a New Haven and Shore Line car operating in the immediate vicinity. To determine the actual maximum value attained by this gradient, a six-hour test was made with a special high sensitivity recorder and non-polarizable electrodes. At the same time an eighteen-hour record of the potential of the trolley rails referred to earth six feet away from the rail was obtained. This gradient record shows a maximum of 282 volts per thousand feet at this location and the potential test showed the rails reversing to earth at times, becoming as much as 70 volts positive in potential to adjacent earth.

It is evident that at practically all locations where tests were made in the Foxon Road territory the voltage gradients existing in the earth were far in excess of the limitation of one volt per thousand feet ordinarily set for reasonably safe electrolysis conditions. In fact the earth gradients along the route of the proposed North Branford water supply line are so high that it would be practically impossible effectively to protect the proposed pipe line against stray current action under existing railway conditions. It is true that generally speaking the soil resistivity is comparatively high and that as a result the existing stray current density in the earth is low. This, however, would merely accentuate trouble on a metallic continuous pipe line which would have to run through the low as well as through the high resistance soil. Stray current interchange between such a pipe line and earth would be extremely localized in the soil areas where the resistivity was very low or moderately low.

In addition, the proposed route involves a long exposure to stray currents and since the pipe will be large in size and low in electrical resistance comparatively large amounts of stray current could be picked up even in the high resistivity soil. For this reason any attempt to break up the electrical continuity of the proposed pipe line with isolated insulating joints would be certain to result in high differences in potential across such joints. Even if every pipe joint were made insulating, a gradient of 32 volts per thousand feet parallel to the pipe, such as exists near Quinnipiac Avenue would mean a potential difference of 0.4 volt across each bell joint. Such a potential would be far too high for safety, with any of the practically feasible non-metallic pipe jointing materials like Leadite or Hydro-Tite.

The high voltage gradients existing in the earth in the Foxon Road territory can only be due to an extremely defective track return circuit system on the railway line in this area, and the obvious remedy is the elimination of these defects. In the case of the Quinnipiac Avenue line, we know that the crossing with the New Haven and Shore Line Railway was in bad condition, because an indicating voltmeter test showed a potential as high as 18 volts across this cross-over both in a north to south as well as in an east to west direction. In the case of the New Haven and Shore Line Railway, visual inspection of short sections of track indicated a large number of bonds missing, and the additional

possibility of existing bonds having a high electrical resistance because of their being of the pin terminal type whose electrical conductivity is not always perfect to begin with and apt to deteriorate with vibration and age. Another factor tending to radically increase stray currents from the Shore Line system was the comparatively long direct-current feed existing at the time of our tests, due to the Totoket Substation of this trolley line being out of service. Apparently this substation was not being operated regularly, and this meant that the entire New Haven and Shore Line Railway was being supplied from the Grand Avenue station of The Connecticut Company in New Haven and a New Haven and Shore Line Substation in Guilford.

CONCLUSIONS

The ultimate safety of the proposed North Branford-New Haven water supply main from stray current hazards demands that the present abnormally excessive track drops existing on the railways in this territory be materially reduced and maintained at a small fraction of their present magnitude. This will involve (a) test of all rail bonds and special work jumper cables, (b) immediate replacement of all missing or defective bonds or special work jumper cables, (c) operation of the Totoket Substation of the New Haven and Shore Line Railway system at least during periods when cars are operating between North Branford and New Haven, and (d) thorough and continuous maintenance of the general electrical conductivity of the track return systems.

Assuming the adoption of such railway return circuit improvements as will reduce track drops and earth gradients to reasonable values, it would be well to break up the electrical continuity of the proposed pipe line at several points on both sides of the Quinnipiac River before the line enters the low wet ground bordering the river. From the data which we have obtained so far, the best locations for insulating joints on the east side of the river would be in the high-resistance soil (a) near Essex Street and Foxon Road; (b) just east of Quinnipiac Avenue; and (c) just west of Quinnipiac Avenue. On the west side of the Quinnipiac River, we understand the line will run in clean river sand along the greater part of Peck Street, and several insulating joints should be installed in this section at locations where the soil resistivity is high and where the joints will not be by-passed by connections to the general water distribution system.

Since the expense of installing insulating joints when a pipe is being laid is comparatively small, we would also suggest the installation of additional insulating joints in the proposed pipe line about 500 feet either side of the crossing with the New Haven and Shore Line tracks on Foxon Road near Eastern Street, and in the Town of Foxon at 1,000-foot intervals along the section where the pipe will closely parallel the trolley tracks.

The electrical effectiveness of all insulating joints should be determined by test both just before and after they are put into the line in order to safeguard against breakdowns resulting from handling. All of the insulating joints and the pipe for a few feet on either side should be covered with an insulating coating of tar or asphalt to increase the length of the earth path around these joints. After the line is complete, tests should be made to ascertain whether or not dangerous shunting action exists at any of the joints. To

facilitate the latter tests it would be well to install permanent electrical test stations, as the pipe is laid, approximately midway between each pair of insulating joints. On the river section of the main, one such test station should be installed two or three hundred feet west of the easterly insulating joint and another, two or three hundred feet east of the westerly insulating joint.

I think I should add that the New Haven and Shore Line Railway is not operated by The Connecticut Company which operates all of the other electric railway lines in New Haven and vicinity and which for many years has closely coöperated with the other utilities in the study and control of electrolysis problems in New Haven and vicinity. The New Haven and Shore Line Railway is passing through one of those periods of readjustment and transition where its future operation is a matter of study and in which very little attention can be paid to operating efficiency or maintenance. This situation, however, emphasizes rather than alters the need for careful consideration of stray earth current hazards by other utilities contemplating the installation of important, expensive, underground structures in the vicinity.

DISCUSSION

C. F. Meyerherm:³ To amplify Mr. Minor's article somewhat, and to show what can be accomplished in the way of practical electrolysis mitigation by the adoption of preventative measures based on a definite knowledge of existing stray current conditions, earth gradients and soil resistivities in the territory through which a proposed pipe line will pass, the following will be of interest.

Several years ago, The Adirondack Power and Light Corporation contemplated laying 16 miles of 12-inch welded joint steel transmission main as the sole gas supply for the city of Schenectady with more than 100,000 population and its large manufacturing plants. Continuity of service was naturally a paramount consideration, and since single-trolley electric railways operated in the territory through which this line was to pass, as well as in the cities of Schenectady and Troy where it was to terminate, it was deemed advisable to protect the line against stray electric railway current.

Accordingly a series of electrolysis tests was undertaken which included potential measurements on the city piping networks at both

³ Consulting Engineer, with Albert F. Ganz, Incorporated, New York, N. Y.

ends of the proposed pipe line and on accessible grounded metallic structures along the pipe line route, track voltage drop and gradient measurements on characteristic sections of the trolley lines and earth gradient and soil resistivity tests at characteristic points along the pipe line route.

The pipe line route selected involved two crossings under trolley tracks, and a general parallelism with the nearest trolley lines. The separation between pipe and tracks ranged from 250 to 1,000 feet for the first $4\frac{1}{2}$ miles of line and then it ranged from $\frac{1}{2}$ to 2 miles for the next 10 or 11 miles. Ordinarily a separation of this magnitude would be assumed to give comparative immunity, but in the present case track drop, potential and earth gradient data collected showed that currents averaging about 25 amperes with maximum values in the neighborhood of 60 or 70 amperes might reasonably be expected to flow on a 12-inch steel line if all joints were welded or otherwise made electrically conducting. A current of this order or magnitude could easily be a serious hazard to a thin walled steel pipe line.

The soil resistivity tests, as in the New Haven case, showed values that were extremely high at some locations, and low at others. The soil resistivity at the points tested ranged from 4,570 to 470,000 ohm centimeters, and the disturbing factor was that the lowest resistance soil occurred in the sections of the route where the pipe line would cross under or be closest to the trolley tracks. In addition, the easterly end of the pipe line included a long crossing under the Hudson River.

To prevent effectively the accumulation of stray electric current on the pipe line, insulating joints were recommended, and because of the specific information on existing stray current conditions obtained from the test it was possible to space the insulating joints so as to meet most effectively local requirements. A spacing of 150 feet was recommended where the exposure to stray current was the worst, and the spacing was increased to 300, to 500 and even to 900 feet in the sections of line where the earth gradients, soil resistivities, and the stray current exposure were proportionately less severe.

For mechanical reasons it was deemed expedient to install some form of expansion joint in the line, and by selecting a type of expansion joint that could easily be made electrically insulating, the actual additional cost of protecting the line against stray current electrolysis was reduced to a negligibly small figure. Approximately 150 insulating expansion joints were installed in the pipe line as it was laid.

After the job was completed, tests were made to determine the electrolysis status of the line in place. These tests showed that of twenty sections tested, no section showed enough current to give a readable average on a special high sensitivity indicating millivoltmeter. In ten cases momentary current swings were detected, but in eight of these the swings meant less than 1 ampere maximum current. The range of instantaneous maximum current values was from 0.07 to 1.4 amperes, and it is worth emphasizing that both of the 1.4 amperes maximum values occurred at a trolley crossing where a 150-foot spacing between insulating joints had been inadvertently increased to 1,000 feet.

These results certainly show the marked benefit obtained from the use of the insulating joints and the matter is doubly interesting from the fact that the practical elimination of stray current hazard from this important pipe line added only a fraction of 1 per cent to the total cost of the line. It indicates an intensely practical engineering method of dealing with new work, and it contrasts strongly with the more or less prevalent practice of waiting for actual failures to develop before thought is given to electrolysis hazards or mitigative measures.

WM. W. BRUSH:⁴ This paper is a valuable addition to the literature on this subject because it points out to us what a good many of us failed to realize in the past, namely, that a survey of electrical conditions before laying out a pipe line is imperative practically. In our practice in New York City we, fortunately, have had very little trouble with electrolysis, but there are locations where we are likely to have trouble. I must confess that up to the time of hearing Mr. Minor's paper I had not thought of making a preliminary survey of the electrical conditions along a proposed pipe line.

We have just finished a repair to a 66-inch steel line in the Borough of Richmond, where the city of New York is responsible for the current. The city of New York took over a rather badly run-down trolley system and tried to run it without much success, financially or otherwise, but during the time it was being operated by the city there were large leakages of current from the rails. The result was that the current reached the 66-inch pipe line and caused electrolysis over a section of approximately 800 feet in length. We have just

⁴ Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

welded about 23,000 pits in this 800-foot section at a cost, for the actual welding, of 27 cents a pit. The total job cost about \$13,000 for uncovering pipe, cleaning, making repairs, and some paving.

That repair job developed from an unusual combination of conditions, but at the present time we are making a survey in Queens along a 60-inch steel line where a substantial current at the present time is flowing along a portion of this new line. I believe, whether the pipe line is of steel or cast iron, that where there seems to be any question about the adequacy of the return of the current so there might be a substantial current flowing through the pipe line, a survey made in advance of locating the line would be a very well worthwhile, precautionary step. Some of us may, as a result of such a survey, utilize joints that are non-conductive to a much greater extent than we have in the past.

ALLEN HAZEN:⁵ As far as cast iron pipe is concerned, the procedure in the west and south in using cement joints pretty well eliminates electrolysis. It makes each pipe a non-conductor. I do not know why the use of cement joints has come so slowly in this part of the country, because it is very advantageous wherever it has been used. It sticks and grows. It seems to be a real protection from electrolysis in the cast iron pipe system.

Steel pipes in our experience have not suffered very much. They are good conductors of electricity.

Mr. Lochridge has used a method for the protection of the pipe at Springfield, which seems to work very well. Where the electricity is leaving the pipe and tends to destroy it, he buries some scrap iron, connects it up with copper wire to the pipe, and lets the electrolysis work on the scrap iron as much as it can.

K. H. LOGAN:⁶ There are only one or two suggestions I should like to bring to your attention. In connection with the laying of the pipe line, I was just wondering if your electrolysis survey could be so made that you could determine definite negative regions, whether it would not be feasible to reduce the amount of current collected by a rather heavy, protective coating. You lay lines usually with a coating. By making that coating a little heavier it might be of

⁵ Consulting Engineer, New York, N. Y.

⁶ Bureau of Standards, Washington, D. C.

considerable assistance in keeping the current off of the line. Of course, when it comes to protecting the pipe in the positive region the problem is quite different, and there I should say the coated pipe should not be coated because the coating would tend to concentrate your current discharge.

In regard to Mr. Lochridge's plan for connecting his pipe to scrap iron, it has been tried in a number of places. How well it works depends upon the relative contact which you have between the soil and the ground, as compared with the contact with the pipe and the earth. Generally speaking, I would suppose that in most locations your contact between your soil and your pipe was so good because of the large surface area of your pipe, and because water usually follows your pipe line anyway, that the additional contact which you get through a buried material would not be of any very great service.

Regarding your pipe drainage plan, of course, if you run your ground connection out toward your street railway system and make a very good ground, you are draining to some extent to your street car railway system, and that does give you local protection.

ASHER ATKINSON:⁷ I would like to ask the gentlemen whether anything has been done to approach this from the trolley situation. For instance, some time ago I tried to determine the resistance of the trolley system in New Brunswick. I took a car out after all other cars had stopped running, that is, only one car on the system, with a voltmeter and observed the loss of voltage. When I was 10 or 12 miles away from the power station the resistance got lower. I concluded that the ground return was getting better on account of being near the Raritan River. Why could not the trolley rails be grounded in wet earth more frequently and get a better return so there would not be so much stray current?

MR. MEYERHERM:³ There is a distinct disadvantage in connecting trolley rails to pipes at outlying points because inherently this procedure increases stray current whereas the primary object of all mitigative measures should be the reduction of stray currents. Fundamentally, the railway return circuit should be metallically continuous and adequate in conductivity to carry the return current with a minimum loss to earth. If rails and pipes are metallically

⁷ City Engineer, New Brunswick, N. J.

connected at outlying points, this would be a direct invitation for return current to leave the rails and flow over the pipes. Stray current flow on the pipes would be materially increased, incidental hazards which attach to such current flow would be correspondingly increased and there would be no practical or theoretical benefit to the pipes. In other words, you would be making matters worse rather than better as far as the pipes are concerned and offering the piping system to the railway for use as a part of their return circuit.

J. WALTER ACKERMAN:⁸ If there is no one else, I should like to report a little experience of my own. This occurred quite a number of years ago, and whether or not the practice is the same today I cannot say. A survey showed that considerable current was going from the rail in our pipe line at various places. However, in one street where the trolley tracks were laid we had one of our large distribution mains. Also in that street there was the entire electrical distribution of the city, both the large telephone cables and the cables of the high tension currents. This street also passed adjacent to the power station. It was done in that particular street because that was the place where the current was leaving the rail and going into the water main, and going into the cable sheaths. The water main, the cable sheaths, and the return wire of the trolley system were all bonded together at every manhole of the conduit system; then at the point where it passed the trolley station very heavy leads were attached to the mains, to the cable sheaths and, of course, to the return of the trolley. That was carried right in to the negative bussbar of the station and an instrument placed there, so that any time the amount passing through could be read. That was a drainage system. I do not know whether that is the present practice or not. That was twenty years ago.

⁸ City Manager, Watertown, N. Y.

THE BUREAU OF STANDARDS SOIL-CORROSION INVESTIGATION¹

By K. H. LOGAN²

It is rather interesting to note that occasionally similar ideas occur almost simultaneously to two persons who are widely separated and unknown to each other. Thus the plan of Mr. Minor for making an electrolysis survey of the proposed route of a water-pipe line, as described in the paper just presented,³ is fundamentally the same as that of the men who made a soil survey of the Denver-Amarilla gas line which was installed a short time ago. In one case the object was to avoid electrolytic corrosion, while, in the other, soil corrosion was to be prevented. The two causes of corrosion are closely associated, and frequently it is difficult to distinguish between them.

The Bureau of Standards soil-corrosion investigation is the outgrowth of its study of stray-current electrolysis. To determine the prevalence and characteristics of corrosion caused by soil conditions and the character of the pipe materials we buried a large number of specimens of different kinds of iron, steel and lead in 1922 and have been removing some of these specimens at approximately two-year intervals. The third set of specimens was removed in the summer of 1928. While we do not think that the exposure of the specimens or the number examined is sufficient to justify final conclusions as to the life or relative merits of the materials, there are a number of things which may be said with confidence concerning the results so far obtained.

One of the most interesting things which we have learned is that it is impossible to distinguish between electrolytic corrosion and soil action by the appearance of the corrosion. In the case of cast iron

¹ Presented before the New York Section meeting, December 28, 1928. Publication approved by the Director of the Bureau of Standards, United States Department of Commerce.

² Electrical Engineer, Bureau of Standards, United States Department of Commerce, Washington, D. C.

³ This Journal, page 299.

the so-called graphitic corrosion products are formed in both cases if the corrosion is rapid. The product is largely ferrous oxide rather than graphite and is formed whenever the supply of oxygen is too limited to allow more complete oxidation.

The distribution of pits on a pipe appears to depend on soil conditions, and the presence of a few widely scattered pits on a pipe does not indicate stray-current electrolysis.

There are some indications that under favorable conditions it may be possible to distinguish between electrolysis and soil corrosion by the change in pH value of the soil adjacent to the seat of corrosion—a decrease in pH value indicating electrolysis, but the investigation of this problem has not gone far enough to show the reliability of this means of identifying electrolytic action.

Although there are some differences in the rates of corrosion of the different kinds of iron and steel, we are impressed by the fact that, in general, if one kind of material corrodes badly in a given soil, all of the other kinds of ferrous materials corrode badly also. Usually, too, the corrosion patterns are similar for the different materials. We are led to the conclusion, therefore, that soil characteristics are the major factors in determining the initial rates of corrosion of ferrous pipe materials. Perhaps this is partly because all of the rolled materials are coated with mill scale and consequently are similar at the surface.

Comparison of the data for the specimens removed at the close of the two- and six-year periods indicates that in a majority of cases the rates of corrosion and pitting are greatest for the first period, i.e., the rates of corrosion decrease with the time of exposure. As specimens grow older the corrosion becomes more general and the rate of penetration slows up more than the rate of loss of weight. We find several soils in which there is little evidence of a decrease in the rate of loss of weight with time, but no soil in which there is not a decrease in the rate of pitting of the rolled specimens.

We have found some soils that are decidedly corrosive with respect to iron and steel. Most of these are in the South and Southwest, although a few corrosive soils are to be found in the Northern and Eastern States.

The question of why soils are corrosive and how such soils can be identified has of course received some attention.

The problem of identifying corrosive soils appears to be difficult. Studies of corrosion in different sections of the country lead us to the

belief that there are several causes of corrosion. In the Eastern soils, soil acidity, texture and rainfall seem to be among the major factors influencing soil corrosion. In the arid regions of the Southwest the kind and amount of soluble salts appear to have marked influence. We are trying to develop methods whereby from a study of samples of a soil and a knowledge of the topography of the region from which the samples were obtained we can predict the corrosiveness of the soil and specify the nature of the protection needed. Indications are that a knowledge of topography, soluble salts, total acidity and colloidal content will form the foundation for a prediction of soil corrosivity, but experience with these soil properties may later show that information concerning some other soil properties is also needed.

The corrosiveness of soil with respect to iron and steel is not an indication of the action of the soil on bituminous coatings and so far as we know no systematic study of the relation of soils to coatings has been undertaken.

Some work related to this problem has been planned by the American Petroleum Institute, which has stationed a research associate at the Bureau of Standards to study protective coatings. His work in the near future will be confined largely to a study of coatings on existing oil lines. It is hoped that he will be able to correlate the condition of the coatings which he examines with the character of the coatings and the conditions to which they are exposed.

Obviously his field observations will raise many questions which can only be answered by laboratory investigations, and unfortunately at this time the Bureau is not able to assign a man to this work. We are, however, carrying on a very limited investigation of methods of testing protective coatings in the hope that some day a standard method will be established. Such a method should enable us to predict the value of a coating for use under specified conditions without waiting for the results of long-time tests on working lines.

Interest in the study of soil corrosion and methods of its mitigation has been steadily growing. A year and a half ago the Cast Iron Pipe Research Association employed a chemist to assist the Bureau in its soil-corrosion work, and much of the development of methods of studying soils has been due to his efforts.

Soil corrosion is such a complex problem and affects so many interests that we feel that it is particularly adapted to coöperative study. Coöperation has been the keynote of the Bureau of Standards

soil-corrosion investigation since its origin in the Research Subcommittee of the American Committee on Electrolysis. More than a hundred organizations are participating in the carrying out of the original investigation. It was for the purpose of securing further aid in the solution of corrosion problems that a soil-corrosion conference was held at the Bureau early in December. To this conference were invited only those who were known to be conducting studies of corrosion or protective coatings, and each organization was required to present a report on some phase of its work. It is rather surprising that with these limitations thirty-four papers were presented at the two-day conference. Among those attending were directors of research departments, metallurgists, chemists, and pipe line electrolysis and consulting engineers. The organizations represented include several gas and oil companies, manufacturers of iron and steel pipe, and makers of protective coatings. The exchange of ideas between men looking at the corrosion problem from so many viewpoints cannot fail to result in a better understanding of the problem all are trying to solve.

That corrosion is an electrolytic process is now generally recognized. The electrolytic theory of corrosion is rather old, but our ideas as to the details of the process and the origins of the potentials are still undergoing changes. Originally non-uniformity in the metal caused by impurities or strains was assumed to account for much of the corrosion. Then Evans and others pointed out that differences at the surface of the metal, oxygen concentration cells, etc., were factors. The soil-corrosion tests indicated that the structure and chemical properties of the soils as well as the nature of the contact between the soil and the pipe must be considered. In the summer of 1927 some tests which the Bureau conducted with the coöperation of a pipe-line company suggested another cause for pipe-line corrosion.

The line under investigation was a 4-inch steel line about 35 miles from the nearest street-railway system. It had been disconnected at each end from the pipe system and was not connected to wells or tanks. Its length was about 30 miles. The country traversed was nearly level but included several low hills and small streams. Beginning about a quarter of a mile from the south end of this pipe line we took the drop in potential across a 20 foot section of the steel pipe and were surprised to find a potential which indicated about a quarter of an ampere flowing northward.

Measurements on successive sections indicated decreasing currents

as we went north until at a distance of about 80 feet we found no current. Beyond this point we found currents flowing south and these increased in magnitude until at a distance of 200 feet a current of 0.7 ampere flowing south was found. Further study of this line showed that more or less current was present on nearly every section, flowing in one direction on some sections, and in the opposite direction on the other sections. Usually there was a gradual increase or decrease in current as we progressed from section to section. At any given pipe section the current was steady and showed about the same values on different days.

Since decrease in current in the direction of flow indicated a loss of current from the line, we were interested to note the relation between loss of current and the condition of the pipe. In general the sections discharging current were found to be in a worse condition than those collecting current.

Similar tests on an 8-inch oil line further west disclosed a maximum current of $4\frac{1}{2}$ amperes. On 7700 feet of this line which were discharging current 66 leaks had occurred, while on 5300 feet of the line where current was collected only 4 leaks were recorded.

There seems to be a relation between the current discharged from the line and corrosion just as there is in stray current electrolysis but in the cases cited it is scarcely possible that stray currents existed. The explanation suggested is that when a line passes through two different soils a galvanic cell is formed the voltage of which depends upon the difference in solution pressure of the metal in the two soils. Oil lines are welded or have screw joints and are very good electrical conductors. Small voltages, therefore, may result in appreciable currents.

The currents are to be regarded as the result of the action of the soil on the pipe rather than as the cause of the corrosion. Nevertheless since the production of current is a necessary result of continued corrosion, anything which will interrupt the flow will reduce the corrosion, just as the opening of the circuit of a primary cell reduces the rate of deterioration of the corroding electrode in the cell. Lead-calked cast-iron water mains have considerably more resistance than welded steel mains of the same capacity and this may result in less galvanic current and less corrosion. We hope to make a study of galvanic currents on a cast iron main this spring. We wish also to establish about 20 permanent test stations where specimens of new pipe materials and coatings which are developed

from time to time can be tried and compared with the materials which have been previously tested. Such test stations will also be helpful in determining the value of accelerated tests developed in the laboratory.

DISCUSSION

MR. COE: I have in mind a town near New York which has recently adopted the use of copper service pipes. If the Bureau of Standards have experts who would be available for advice in such a case, it would be very valuable for this town to get in touch with such field representatives. Is such a service rendered?

MR. LOGAN:² We do some consulting service by correspondence, but that is about all. Possibly you are not aware that the Bureau conducted a study of electrolysis on copper service pipe and reported to the Water Works convention in San Francisco last June.⁴ Briefly, we find that, as far as corrosion in the soils we have tried, copper stands up very well. Brass service pipe which is high in copper also appears to stand up well. When it comes to electrolysis I think that copper has no virtue over steel or iron. Some people have made a claim that due to its higher conductivity it would carry off the current, but I do not think that is the case. Our data indicated that the rate of electrolytic corrosion by copper was about the same as iron and steel.

WM. W. BRUSH:⁵ We are rather fortunate in New York City in having a relatively low corrosive factor in our soils. There are very few locations in the city where the experience to date has indicated any serious trouble from soil corrosion. We have a great deal of trouble from the internal corrosion to which some have feelingly referred. Most of us who have to do with water works in this section of the country have that experience.

From the strictly technical viewpoint the majority of us who are operators believe that we cannot helpfully discuss the question of corrosion but must rely on those who specialize in this field. Only recently the pipe manufacturers had become sufficiently interested to financially support an independent study of this subject which is

⁴ Journal, September 1928, page 390.

⁵ Chief Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.

being undertaken in connection with the standardization of cast iron pipe and fittings. The American Water Works Association, the Gas Association, the New England Water Works Association and the American Society for Testing Materials are adding their financial support, although the manufacturers are furnishing the greater part of the funds for this purpose.

When there are so many interested in the study and solution of a problem we may all be hopeful as to the result. We shall expect those who are making this study to interpret the results in such a manner that they can be effectively utilized by all of us.

It is rather surprising how slowly use is made of what other people have determined as a result of their experience or investigation in correcting our troubles. Here in the East we put in water pipe with the same coating that was used years ago, which is virtually good for nothing. Our pipe rapidly lowers in carrying capacity and still we are very slow in adopting either an effective coating or in really determining what is the action we ought to take for the benefit of the communities we serve.

We will be spurred into more effective and more intelligent action by the work being done by others in making this study. We will feel more certain that we are correcting or going a long way toward correcting our corrosion troubles with the information furnished us by the Bureau of Standards and other investigating bodies and groups now at work on these problems.

OPERATING EXPERIENCES WITH THE WATER PURIFICATION PLANTS OF THE EAST BAY WATER COMPANY¹

BY WILFRED E. LANGELIER² AND JOSEPH D. DeCOSTA³

The East Bay Water Company supplies water to Oakland and Berkeley, California, and other adjoining municipalities on the east side of San Francisco bay.⁴ The average daily consumption of water for last year was 32 million gallons, approximately two-thirds of which was filtered water from surface sources. There are two major filtration plants, the San Pablo plant located just north of Berkeley and the Upper San Leandro plant 15 miles to the southeast in Oakland.

These plants have been described in engineering literature, (1) (2), and therefore this paper will be confined to a discussion of certain operating experiences which it is believed should be of general interest. Only the briefest reference to design features, essential to elucidation of operating problems, will be made.

RAW WATER SUPPLIES

Both plants are supplied with impounded waters of practically identical composition. The watersheds lie adjacent to one another and are of similar physical character. In general, these waters are characterized by moderately high organic and mineral content and the reservoirs are subject to heavy growths of plankton or algae. The turbidities are flashy. During the heaviest run-off season, usually in February, the raw waters may attain turbidities of 2,000 or more parts per million. Two weeks later the turbidities may have dropped to 25 p.p.m. and may not rise above this value for a full year.

¹ Presented before the Water Purification Division, the San Francisco Convention, June 14, 1928.

² Associate Professor of Sanitary Engineering, University of California and Consulting Sanitary Engineer, East Bay Water Company, Berkeley, Calif.

³ Assistant Sanitary Engineer, East Bay Water Company, Berkeley, Calif.

⁴ Since the preparation of this paper, the plant of the East Bay Water Company has been purchased and is being operated by the East Bay Municipal Utility District.

The soluble and colloidal organic matter, mostly of vegetable origin, is continuously high. This is indicated by oxygen consumed values of approximately 10 and color of 40 p.p.m. A chlorine absorption test made recently gave a result of 70 pounds per million gallons, equivalent to 8.4 p.p.m. These raw waters are capable of absorbing chlorine gas to upwards of 20 pounds per million gallons without causing taste or odor. That some of the organic matter is in colloidal suspension is indicated by the fact that the filtered water, although apparently clear, shows a marked Tyndall effect. It is practically impossible, with the use of ordinary alum dosages, to reduce the color to less than 15 p.p.m.

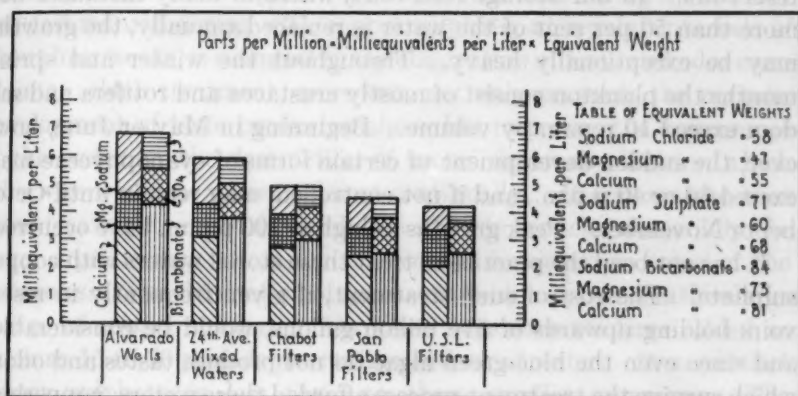


FIG. 1. GRAPHS SHOWING THE MINERAL CHARACTER OF SAMPLES

The hardness of either water is slightly greater than its alkalinity and averages 3.5 milli-equivalents per liter or 175 p. p. m. The equivalent sodium-magnesium-calcium ratios are approximately 1.0, 1.25, 2.25, and the chloride-sulphate-bicarbonate ratios 0.75, 1.0, 2.75. The reaction of the water is slightly alkaline, pH = 7.6.

The watershed lands that produce run-off water of this character are only sparsely wooded. Possibly 25 per cent of the land is forested. The top soil is mostly clay. The lands are 70 per cent owned by the company and the density of population is very low, so human pollution is a negligible factor in the purification process. Last year only 10 per cent of twelve hundred 10 cc. portions of raw water tested were found positive for methyl red positive organisms of the colon group.

Other characteristics of the raw water which relate to the problems of purification are the seasonal presence of plankton growths, more particularly the blue-green types of floating algae, and traces of manganese, both of which may be very troublesome in connection with filtration. These characteristics already have been referred to in published articles (3) and (4), but for the sake of completeness will be discussed further herein.

PLANKTON

In this region, plankton or algae, if permitted, may grow abundantly the year around in practically all storage and open distributing reservoirs. In our storage reservoirs, where in many instances not more than 50 per cent of the water is replaced annually, the growths may be exceptionally heavy. Throughout the winter and spring months the plankton consist of mostly crustacea and rotifera and seldom exceed 10 p.p.m. by volume. Beginning in May or June, however, the sudden development of certain forms of cyanophyceae may exceed 30 or 40 p.p.m., and if not controlled, may remain until October or November. Peak growths as high as 200 p.p.m. have occurred.

It has not been the practice to treat these stored waters with copper sulphate. The cost of such treatment, if given frequently in reservoirs holding upwards of five billion gallons, would be considerable, and since even the blue-green algae do not produce tastes and odors which survive the treatment process afforded these waters, coppering, up to the present time, has not been considered necessary.

In addition to the crustacea which are present in varying density throughout the year, the predominating and most characteristic organism in the storage reservoirs is the blue-green alga, aphanizomenon. This organism has made its appearance each year and when the growth is at its peak a scum forms on the quiet waters around the margin of the reservoir which in places may be one-quarter of an inch thick. Away from the shore the large masses are broken up by wave action, but the characteristic tiny clusters may be seen with the naked eye. Although this organism is reputed to impart to water a characteristic grassy taste and odor, our experience indicates that, in the supplies under consideration, taste and odor production is negligible until the organisms are undergoing decomposition. At such times the moldy odor, commonly associated with decay of vegetable matters, is usually noted. During periods of heavy growth, the removal from the water of the organisms themselves may add a heavy

burden to the filter units. This burden is considerably lessened by excluding, from entrance into the intake, waters from the upper strata of the reservoir. These organisms do not penetrate, in large numbers, depths below 25 feet except on very windy days. Treatment of the water at the intake with chlorine kills the organisms, but such treatment has not proven to be an advantage. Only a small portion of the organisms either dead or alive can be removed in the sedimentation basins after coagulation. When these growths are heaviest, the salvaging of the wash water from the filters, as ordinarily practiced, is dispensed with.

In the uncovered distributing reservoirs much algae trouble has been experienced in the past. We have found that during the summer and fall months dosing with copper sulphate, at regular intervals of about four weeks, is essential to the elimination of taste and odor complaints. Such treatment, moreover, not only prevents the periodic development of taste producing algae, but improves the appearance of the water by the destruction of brownish nanno-plankton which otherwise would be present almost continually. It appears also that these treatments exert a cumulative effect in reducing materially the larger aquatic vegetation which formerly developed in some of the reservoirs. The elimination of nanno-plankton requires a rather large dosage of copper sulphate. On a few occasions we have added as much as 15 to 20 pounds per million gallons of water. It seems that copper sulphate is less toxic to these smaller organisms. The effectiveness of chlorine in the destruction of bacteria would indicate the possibility that such treatment would be more effective than copper sulphate in the destruction of these smaller algae, but we have, as yet, no conclusive data on this matter.

FILTER SAND TROUBLES

Within a few months after the San Pablo plant was placed in operation in 1921, a dark brown or almost black discoloration of the sand grains in the filter units was observed. This indicated the possible presence of manganese in the raw water and analyses confirmed this suspicion. The manganese content was found to be quite small, however, being somewhat less than one-tenth of a part per million. Realizing the damage that might result from permitting a manganese-bearing water to enter the distribution system, and also realizing the effectiveness of manganese-coated sand in removing manganese from water, it seemed desirable not to interfere with its further deposition.

The discoloration and subsequent incrustation of the sand began at the top of the bed, where the finest sand lay, and gradually worked downwards. The first indication of any unfavorable effect was observed in connection with filter washing. The incrustated sand showed a marked tendency to cake, thereby causing the wash water to jet through the sand unevenly. In the course of a few months it became necessary to prod the beds thoroughly with rakes while admitting wash water. The conditions of the sand kept getting worse until, in the summer of 1923, two years after beginning plant operation, under water cracking of the sand beds in very serious form occurred. At this time the upper six inches of sand had accumulated a heavy coating, equivalent to 20 per cent by weight. The amount of incrustation decreased with depth, averaging only a little over one per cent for the bottom six inches. Analysis of the dried incrustation showed it to contain: Organic matter 60 per cent, aluminum oxide 26 per cent, and manganese dioxide 11.5 per cent. Describing this condition at the time, (3) it was stated:

The incrustation as found on the sand grains when a filter is drained is heavily hydrated, and when the sand is compressed in the hand the feel is like that produced by squeezing a handful of granular cork or rubber. The wet sand is also very plastic, so much so that a rod forced into the sand to the gravel layer, upon withdrawal will leave a perfect impression. If the wash water is then turned on, a jet will be formed at this point.

Much has been written concerning filter sand incrustation and filter bed cracking which is sometimes associated with it. Our observations lead us to believe that filter sand incrustation may develop regardless of the character of the sand, provided the water is of a certain character and contains essential constituents, as for example, traces of manganese, colloidal calcium carbonate, suspended organic matter, etc.; and that cracking may occur if the coated sand is sufficiently compressible and subject to vertical stratification with relatively incompressible clean sand from underneath and brought to the surface by the jetting action of the wash water. We believe that the cracks are formed by unequal settlement of the sand bed, and that having once formed are subject to enlargement as a result of lateral compression of the vertical filtering surfaces. The correctness of this theory was indicated by frequent examinations of the sand on opposite sides of a crack and also from the observation that when a filter was drained immediately after washing, small cracks were

formed upon standing, and always in a plane of vertical stratification.

It occurred to us that a system of washing more effective than the high rate water wash and the temporary expedient of hand raking would be desirable. These units are designed with perforated pipe underdrainage and it seemed a very simple matter to adapt them to supplementary air agitation. It was assumed that a preliminary

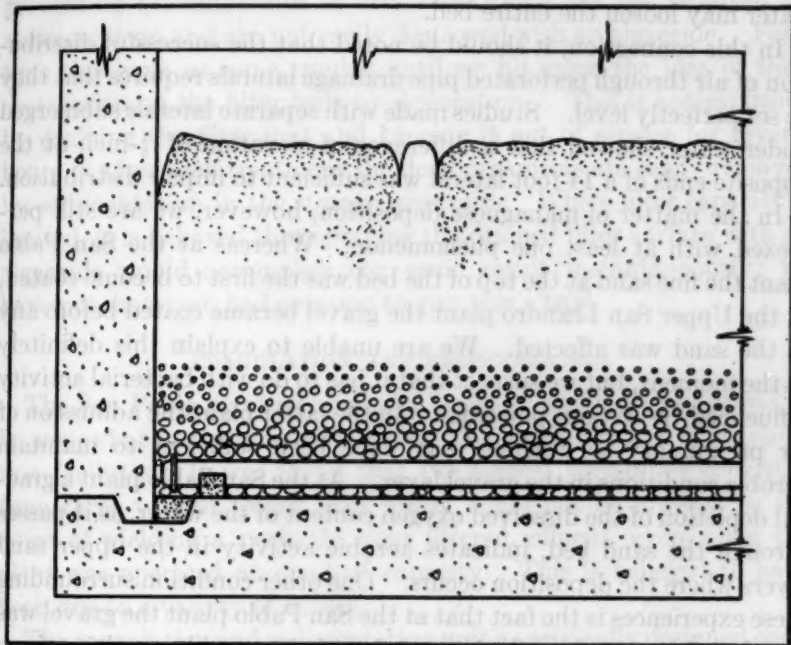


FIG. 2. SECTION OF FILTER SHOWING INCRUSTED SAND AND CRACK FORMATION CAUSED BY VERTICAL STRATIFICATION

blowing of air through the bed would loosen the compacted sand and permit of a better wash water distribution.

Accordingly, a complete unit was dismantled, the laterals carefully leveled, and the central manifold tapped to admit air. This unit was operated through a full season with excellent results and complete freedom from cracking. The following year the remainder of the units were treated in a similar manner. Since the introduction of air application preliminary to the water wash, we have not once observed any cracking of the sand.

With this experience as a guide, the newer Upper San Leandro plant was designed for both preliminary air application and high rate water wash. We are convinced that air application is a cheap and effective method of preventing filter troubles caused by sand that has become plastic through coating of the grains. We have observed that the application of air in this manner does not materially agitate the sand. Its effectiveness depends upon a mere piercing of the plastic sand directly above each orifice such that subsequently the water may loosen the entire bed.

In this connection, it should be noted that the successful distribution of air through perforated pipe drainage laterals requires that they be set perfectly level. Studies made with separate laterals submerged under water showed that a difference of elevation of $\frac{1}{8}$ -inch at the opposite ends of a 14-foot lateral was sufficient to impair distribution.

In the matter of manganese deposition, however, we are still perplexed with at least one phenomenon. Whereas at the San Pablo plant the fine sand at the top of the bed was the first to become coated, at the Upper San Leandro plant the gravel became coated before any of the sand was affected. We are unable to explain this definitely at the moment, but we suspect that it has to do with bacterial activity influenced by oxygen potential. In the latter plant the admission of air preliminary to washing may have been sufficient to maintain aerobic conditions in the gravel layer. At the San Pablo plant a gradual depletion of the dissolved oxygen content of the water, as it passes through the sand bed, indicates aerobic activity in the upper sand layers where the deposition occurs. One other condition surrounding these experiences is the fact that at the San Pablo plant the gravel was found to be quite heavily incrustated with iron oxide resulting from corrosion of the steel underdrains. It is well known that manganese oxides are not readily precipitated in the presence of ferrous iron. At the Upper San Leandro plant the underdrains are of brass tubing and iron deposits in the gravel are absent.

SALVAGE OF SOILED WASH WATERS

The high cost of raw water development in this locality is such as to warrant the salvaging of soiled wash waters. This is accomplished at both plants with the use of suitable storage basins and pumping equipment. At times of excessive plankton growth, it is necessary to waste some of these waters for short periods each year. We estimate, however, that upwards of 95 per cent of these waters are

redeemed, and this at a very considerable saving in water development costs. Throughout the greater part of the year the quality of this water after sedimentation compares very favorably with that of the original raw water. We believe that the ideal basin should provide a capacity equal to the wash water production for twenty-four hours, the return of the water to be distributed over a period of about twelve hours.

One item of interest in this connection relates to the problem of preventing accumulations of crustacea which are not removed by sedimentation and are not easily destroyed with an algacide. For a time this gave us some trouble until we hit upon the idea of their destruction on the filter beds by desiccation. This is accomplished by draining the filter unit and keeping it out of service for several hours. After such treatment the dead organisms are easily removed by sedimentation in the storage reservoirs. Where filter capacity is limited, it is believed that spraying the drained filter surface with an algacide would accomplish the same result instantaneously; we have not, however, had occasion to give this a trial.

COAGULATION AND SEDIMENTATION

The San Pablo plant as originally designed and built was found to be somewhat inadequate with respect to coagulation and sedimentation facilities. It was found that the highest turbidities occurring from three to four weeks each winter could not be lowered to the point of yielding a perfectly clear filtered effluent, even when the plant was operated at one-half capacity. This is believed to have been due to a variety of causes.

The coagulation and sedimentation unit as originally designed comprised two rather long rectangular basins, separated longitudinally by a shallow mixing channel, equipped with the usual "over and under" type of wooden baffles. The arrangement was such that the sedimentation basins could be operated only in parallel. Short circuiting occurred in these basins to an abnormal extent, due partly to the absence of suitable and properly designed inlet and outlet facilities. Wing baffle walls were first experimented with, but the results were not altogether satisfactory. Later, laboratory experiments indicated the desirability of double coagulation and sedimentation for the preliminary treatment of this water. In 1924 the basins were temporarily equipped to operate in this manner. The results were so satisfactory that permanent alterations were later made.

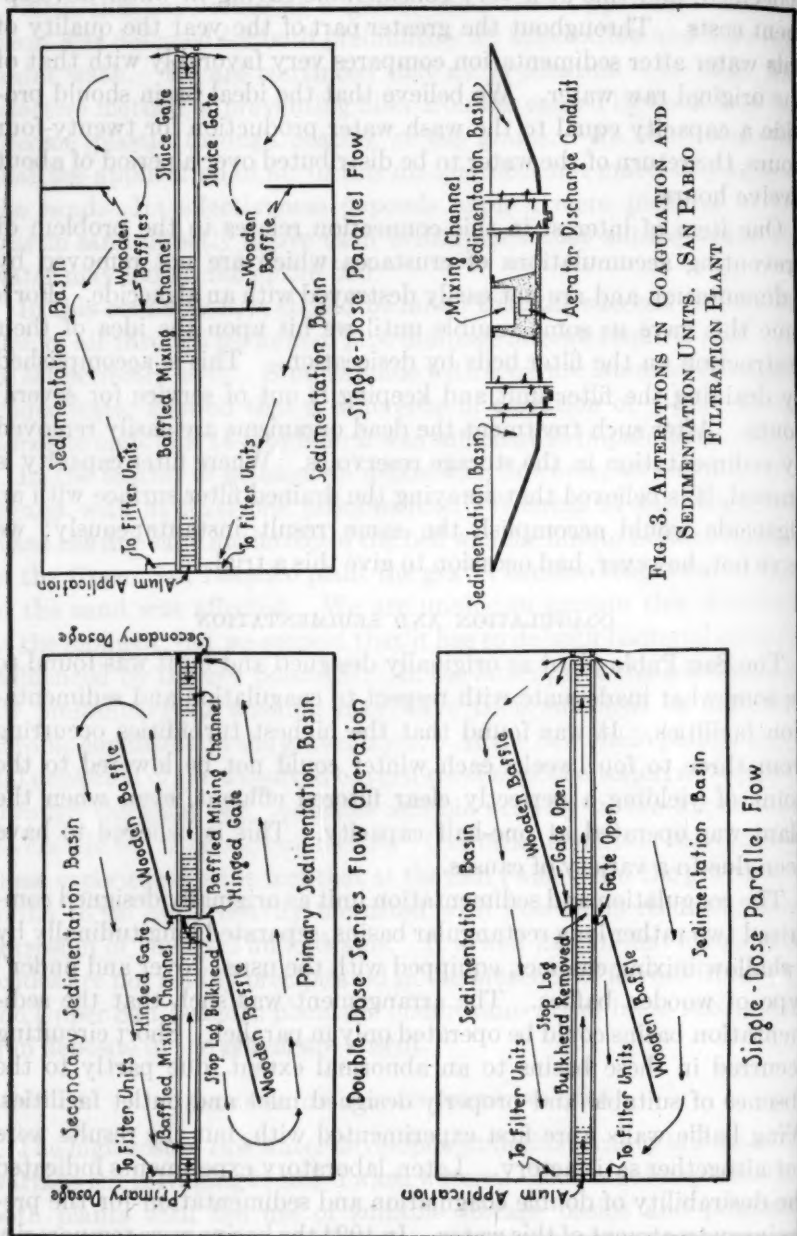


FIG. 3. ALTERATIONS IN COAGULATION AND
SEDIMENTATION UNITS, SAN PABLO
FILTRATION PLANT

The problem of converting the existing parallel flow basins into series flow with double treatment and mixing was solved in what we regard to be a rather unique and highly satisfactory arrangement. This can best be visualized by reference to figure 3.

The mixing channel was blocked off at the middle point. On opposite sides of this bulkhead and in opposite walls of the channel an outlet weir into each basin was made. Opposite these outlet weirs, and somewhat diagonally toward opposite ends of each basin, a wooden baffle wall was installed. With this arrangement the water is given a primary dosage of alum, after which it flows through one-half of the total length of mixing channel, is diverted into the primary settling basin, through which it flows in a gradually retarded velocity into the far end of the mixing channel, where it receives a second dosage of alum. The water then travels back through the secondary mixing channel toward the center of the unit, over the second outlet weir into the secondary settling basin, in which the path of flow corresponds to that in the primary basin. Conversion of the unit to single dosage and parallel flow is accomplished by removal of the channel bulkhead and by closing the adjacent weir openings with stop logs, so that the water may travel directly to the far end of the channel. At this point in each wall a large weir has been installed to replace the original 24-inch sluice gates. A simple adjustment of each baffle wall, made possible by a free hinged end, has the effect of converting a portion of each basin into two parallel flow compartments. Experience indicates that the baffles in this position are desirable in that they assist in preventing transverse currents.

These simple alterations were carried out at very small cost and have had the effect of greatly increasing the efficiency and capacity of the whole plant, especially during periods of high turbidity.

Tests of normal operation this past winter showed that with a raw water of 1000 p.p.m. turbidity, a clarification efficiency of 90 per cent was obtained in the primary unit, and 80 per cent in the secondary unit, making a total reduction of 98 per cent, resulting in an applied water turbidity of 20 p.p.m. The alum dosages in the two units were 4 and 2 grains per gallon, respectively. Unfortunately, at this plant the total available mixing period at normal capacity of the plant is only ten minutes. A longer period would undoubtedly produce a more rapidly settling floc with a smaller alum dosage. This fact is indicated by laboratory experiment and from our experience in operating the Upper San Leandro plant where a mixing period of 25 minutes is

provided. This latter plant has been in operation but little over a year. It was designed with the San Pablo experiences in mind and we are pleased to say that it is functioning excellently and in complete accordance with our expectations.

CIRCULAR COAGULATION TANKS AT UPPER SAN LEANDRO PLANT

Circular coagulation tanks with mechanical stirring, used originally at Sacramento⁵ and in slightly modified form at this plant, constitute perhaps the most interesting feature of design. These units differ from the Sacramento units more particularly in the matter of the ratio

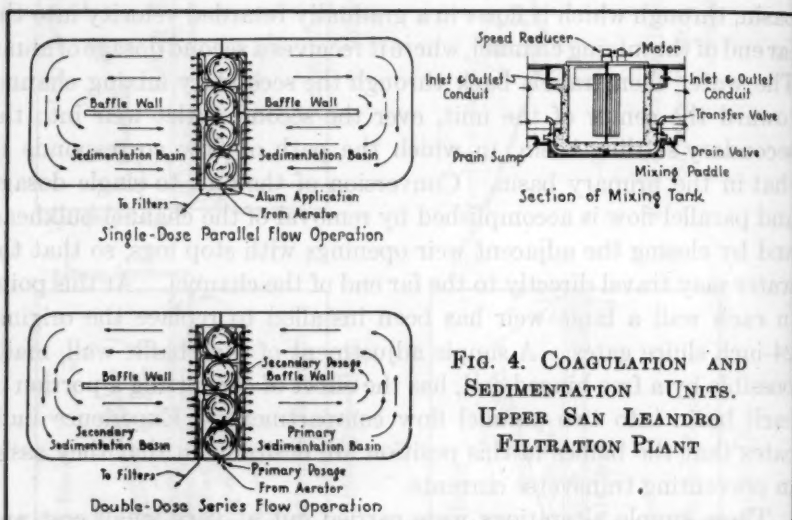


FIG. 4. COAGULATION AND SEDIMENTATION UNITS. UPPER SAN LEANDRO FILTRATION PLANT

of paddle width to tank diameter. In the Sacramento design this ratio is 0.9, whereas in the Upper San Leandro plant the ratio is 0.24.

Paddles of this type have a lower starting torque and permit of much lower gear reduction. They are particularly well adapted to small units, since in these the paddle tip velocities are not excessive. Studies of these ratios with respect to hydraulic characteristics and other operating features are in progress and will be discussed in a later paper.

The high coagulation and sedimentation efficiencies at the Upper San Leandro plant are important factors in reducing the burden on the filter units to a minimum. The average dosage of alum used

⁵ Langelier, W. F., Engineering News-Record, vol. 86, 22, June 2, 1921.

at this plant for the entire first year of its operation was 0.89 grain per gallon as compared to 1.73 grains per gallon at the San Pablo plant. Applied water turbidities moreover, were lower, averaging 10 and 15 p.p.m. respectively.

The mechanical mixing devices and exceptionally large water ways at the Upper San Leandro plant permit of a practically negligible loss of head in the coagulation and sedimentation basins. Actual measurement at the rated capacity of the plant shows this loss to be only 1 inch. The San Pablo loss of head with present baffling is 16 inches which, at actual cost of pumping of seven cents per foot, per million gallons, would be \$1.13 per day for the rated capacity of the plant. Electrical input at the Upper San Leandro plant for the four units is 3.6 H.P. equivalent to \$1.03 power cost per day also based on the same and actual rate for power. Although the costs are roughly equal, it should be noted that the mechanically operated units provide a retention period 2.5 times greater. Moreover, the mean velocities in these units are higher averaging 1.3, as compared to 0.8 feet per second for the gravity mixing channel.

CHLORINATION

All filtered water is chlorinated, as a general safety measure, because even the raw waters fall within the United States Public Health Service Standards throughout most of the year. The dosages vary from 2.5 to 8.5 pounds per million gallons and are controlled by frequent toluidin tests. Our operators try to maintain between 0.5 and 1.0 pound of residual chlorine per million gallons, ten minutes after application.

One ton chlorine cylinders have been in use since November, 1926, and we believe them to be the safest, cheapest and most reliable form of container for plants or groups of plants within a trucking radius of each other using a minimum of say 15 tons of chlorine per year.

CONCLUDING REMARKS

In the operation of these and other plants of this company, other problems have been encountered and interesting experiences gained. The Upper San Leandro plant, for example, is located in a built-up but unsewered district. Resort to sludge drying has been necessary. Interesting problems in watershed sanitation have been encountered. The sanitary department has been much concerned over the problem of existing cross-connections of the distribution system with private

supplies and much work has been done toward effecting their elimination. Bacteriological and chemical tests are the basis of plant operation and these tests are made by the plant operators themselves under the supervision of the sanitary engineer. In a diversified water system such as the one under consideration, where there are, for example, some thirty or more different pressure zones, each with its balancing reservoir, the difficulties associated with dead ends and stagnant water become acute. Intensive work of the sanitary engineer during the past few years in systematically investigating and following up consumer complaints of bad water has reduced their frequency greatly.

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WATER SUPPLY OF THE FLORIDA EAST COAST RAILROAD¹

BY H. P. BOONE²

The investigation and development of a water supply adequate and suitable for the high pressure locomotive boilers of the Florida East Coast Railway Company leads the engineer into two questions of extreme importance, the first being the demand which will at present and in the future be made upon the water station, and second the quality of the water to be provided to be such that it will be most economical from an operating and maintenance standpoint.

The Florida East Coast Railway Company is probably the leader in the south in seasonal demand upon its water stations. During the winter season with the heavy traffic the demand for water will increase from 200 to 400 per cent over the requirements of the previous summer season. Consequently in the design of a water station it is necessary to consider only the maximum demand during periods of heavy traffic, which necessitates a plant of considerably greater capacity than the average of an annual consumption.

One of the foremost and chief points to be considered in any contemplated water station is a source of supply which will be free from excessive amounts of salt water.

The sources of supply used for locomotive feed water along the east coast of the state may be readily classed into three general divisions, deep wells, shallow wells and surface drainage. In general each division is confined to a geographic section of the coast.

The section of the coast in which artesian wells are obtainable extends from Jacksonville southward to Fort Pierce, but from the standpoint of suitable water for locomotive use the area is limited to the territory between Jacksonville and New Smyrna, as the water from artesian wells in the district between New Smyrna and Fort Pierce contains prohibitive amounts of sodium chloride.

¹ Presented before the Florida Section meeting, April 4, 1928.

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An interesting characteristic of the water obtained from artesian wells is that the water from wells in the vicinity of Jacksonville contains approximately five times the amount of sulphate hardness as the water from artesian wells in the vicinity of New Smyrna, although the water from either location contains approximately the same amount of dissolved calcium and magnesium salts.

Shallow wells are numerous in the vicinity from West Palm Beach south to the end of the coast. The usual depths are from 60 to 100 feet. Water from wells in this region contain considerable carbonate hardness, which after removal by chemical treatment leaves a good boiler feed water.

History is known of a well being drilled in the vicinity of Homestead to a total depth of 322 feet, with the major amount of water being found around the 60-foot level, with very little increase in production as the well was being drilled deeper. The effect upon the well as the depth increased beyond the 60-foot level, was that with the slow increase in production there was a distinctly rapid increase in sodium chloride and a proportional increase in brackishness. The well was later plugged at the 90-foot depth and has been used daily for many years without material change in the quality of the water produced.

Surface water is, in general, used in the district between New Smyrna and West Palm Beach. Few of these sources of supply are entirely dependable during a prolonged drought except when the demand for water is exceptionally light. The quality of water from surface sources is quite variable, depending upon the quantity of water available, the recent rainfall in the immediate vicinity and the nature of the soil in contact with the surface water.

During the construction program of 1925 and 1926, which included the second main track between Jacksonville and Miami together with the building of new freight terminals and mechanical facilities, considerable water station work was done.

At each of the new terminals, Bowden at the north and Hialeah at the south end, a water station was necessary. At Bowden, it was determined, after a study had been made which involved the construction of several test wells, that artesian wells would be necessary to provide the quantity which would be required to supply the capacity of the line. Following the decision to use artesian water, two wells were drilled to depths of 731 and 739 feet, respectively.

When the wells were completed and tested it was found that each would flow approximately 900 gallons per minute and could be

pumped at a rate of 1100 gallons per minute with the water level drawn down only about 4 feet.

With the completion of the wells it was determined by chemical analysis that the dissolved calcium and magnesium salts should be removed for economic reasons, consequently a treatment plant was constructed.

The treatment plant which was built has a capacity of 50,000 gallons per hour, with ground operated mixing and proportioning chemical equipment. The tank used is a combination storage and treatment tank having a total capacity of 450,000 gallons of which 200,000 gallon space is available for treated water. The pumping equipment installed is a 6-inch, double suction, horizontal, split case centrifugal pump with dual drive, designed to operate at 833 gallons per minute against a total head of 71 feet with an efficiency of 65 per cent. The primary power unit is a constant speed, alternating current electric motor with a four cylinder, four cycle gasoline engine as an auxiliary power unit. The chemical mixing and proportioning equipment is driven by a constant speed electric motor which insures a constant amount of well mixed chemicals being delivered to the top of the tank where the raw water is mixed with the chemical solution. The flow of raw water is controlled by an automatic flow control valve which maintains a constant quantity in to which the chemicals are mixed by flowing through a weir box. Two buildings of permanent, fire proof construction were erected. One being used to house the pump and its power units, while the other contains the chemical mixing and proportioning equipment and storage space for several car loads of chemical supplies.

The plant which was installed at the Hialeah Terminal is practically a duplicate of the Bowden plant, except that three shallow wells were installed and three separate units of pumping equipment were used. Each of the pumping units consists of a 4-inch, double suction, horizontal, split case centrifugal pump designed to deliver 420 gallons per minute against a total head of 71 feet with an efficiency of 65 per cent. All pumps are arranged for dual drive, a constant speed, alternating current, electric motor as the primary power unit, augmented by a four cylinder, four cycle gasoline engine.

The construction of the Moultrie Cut-Off, a new double track line, thirty miles long, connecting St. Augustine and Bunnell, necessitated the provision of a new main line water station on the Cut-Off. A study with test wells was made in the vicinity where it

was believed that a water station should be located, but the investigation did not indicate that water in sufficient quantity could be secured along the newly established right-of-way. Since the Company had a proven supply of locomotive feed water in Lake Windermere located at Neoga on the old main line about five miles north of Bunnell, it was decided to rebuild the Neoga water station which had previously supplied the tanks at Neoga and Espanola, and supply not only the Neoga and Espanola tanks, but to pipe water to the new water station which was to be constructed on the Cut-Off.

On September 24, 1925 a contract was let covering the rebuilding of the pumping station, furnishing and erecting a 100,000-gallon steel storage tank, two water columns and pits for same, installing pumping machinery, together with the installation of 1380 feet of 12-inch and 15,900 feet of 10-inch cast iron pipe all of which was to be completed by December 15, 1925, as it was expected that the track would be ready for service not later than January 1, 1926. About the 15th of October it was decided that the Moultrie Cut-Off would be opened for train service on December 1, and water must be available at the water columns at that time.

By expediting shipments any way possible and by speedy work of the contractor it was possible to have water available at the points of service one day before the appointed time. The installation of the 15,900 feet of 10-inch and the 1380 feet of 12-inch pipe, together with the necessary temporary connections had been made and the most hurried water station construction had been completed in such shape that water was available.

The Neoga pumping station was a steam plant using wood as fuel, but inefficient, uneconomical and inadequate when the new and greater demand was thrown upon it. Consequently a new pump house was built as more space was required to house the duplicate units of 20 h.p., oil burning, internal combustion engines and the double suction, horizontal, split case centrifugal pumps, which are designed to deliver 500 gallons per minute against a total head of 85 feet at 69 per cent efficiency. The connection between pump and engine was made by an enclosed type speed transforming gear.

At New Smyrna, the principal intermediate terminal between Jacksonville and Miami, the heavy traffic taxed the water station beyond the physical limit of its ability to supply the demand.

The pumping station was located about two and one-half miles west of the New Smyrna Yards and was equipped with two elec-

trically driven, high speed centrifugal pumps, delivering approximately 500 gallons per minute through an 8-inch line to a treating plant in the yards at New Smyrna.

On investigation it was determined that a plant of at least 50,000 gallons per hour would be required to supply the demand for locomotives and shop facilities.

To pump water at the rate of 50,000 gallons per hour it was found economical to replace the present 8- with a 12-inch line, and replace the pumps with pumps with characteristics to fit the new conditions, as the renewal and enlargement of the discharge line reduced the pumping head against which the pumps were working from 185 to 96 feet, which made a substantial reduction in power consumption.

Three, 3-inch, double suction, horizontal, split case centrifugal pumps were installed, one having a capacity of 350 gallons per minute against 96 feet head while the other two are of the same size and characteristics of design, but have a capacity of 500 gallons per minute against a total head of 96 feet with an efficiency of 69 per cent. All of the pumps are direct connected to constant speed alternating current electric motors as primary power units, while one of 500 gallon per minutes units may be operated with a four cylinder, four cycle gasoline engine in event there is a failure in the current supply.

It was also necessary to increase the softening and storage capacity. A 30,000 gallon per hour plant was retained and a 20,000 gallon per hour combination plant was erected, which provided for an additional 100,000 gallon storage space for treated water. With the completion of the new plant the water station was able to meet the variable demand in an efficient manner as either could be operated by using the pump of the proper size, or both softeners could be operated in parallel with two pumps delivering the raw water.

The pumps are controlled by switches located in the vicinity of the softening plants, thus eliminating to a marked degree the labor necessary to operate a plant where the pumping equipment is located remotely from the point where the water is delivered for treatment.

To supply the yard and shop facilities with untreated water for general uses, including fire protection, a booster pump was installed to draw raw water from the common discharge line from the raw water pumps and deliver same into an existing altitude tank.

The four water stations mentioned are the principal stations between Jacksonville and Miami and may be relied upon to furnish

consistently 35 per cent of the demand to supply locomotives and shop facilities along the double track route to Miami.

One of the interesting features of the water supply is the provision made to furnish fresh water for locomotives, drinking and culinary purposes on the series of islands from the mainland to the port at Key West. Since the extension of tracks over the Keys, which was completed in 1912, water has been hauled in tank cars to Key West and intermediate points. The maximum distance from the water station at Homestead to a point of delivery being 128 miles. The loaded tank cars are handled on local or through freights and by water trains which are operated for the purpose of distributing water to the various stations and employees residing along the Over Sea route.

During the year 1926 there were 96,254,000 gallons of water pumped, treated and delivered to the storage tanks at the Homestead water station, of which 37,000,000 gallons were transported the maximum haul being delivered to Key West, and 57,400,000 gallons were distributed at various points along the Road. The Key West water station serves principally as an unloading and distributing point. Fresh water being furnished not only to locomotive boilers, but to the various boats entering and leaving the port of Key West and to the Casa Marina Hotel, which is operated by the Florida East Coast Hotel Company.

The water which has been hauled 128 miles is considered too expensive for boiler washing purposes, consequently the boiler washing which is done at Key West involves the use of sea water after which the boilers are flushed and filled with fresh water.

There is a surprising variation in the problems encountered in the investigation and development of an adequate, dependable and economical water supply, in that each station has individual features and becomes anything but monotonous with closer investigation and further study.

WATER SUPPLY CHEMISTRY ON THE FLORIDA EAST COAST RAILROAD—ITS COST AND BENEFITS¹

By W. H. HOBBS²

The present water softening system on the Florida East Coast Railway was begun with the erection of one plant as a trial at Wonderwood on the branch line running from Jacksonville to the seashore in February, 1906. At that time this branch, now of relatively minor importance, was one of the busiest portions of the railroad because with the locomotives depending on coal for fuel and with the present deep channel to Jacksonville uncompleted, over this line was hauled not only all of the fuel for the road but most of the water shipped exports of the eastern coast of Florida as well.

The results obtained by this installation were so conclusively beneficial that it was decided to extend the use of water softeners as rapidly as finances permitted. By 1909, every water supply down to St. Augustine had been protected; by 1923, nine stations embracing the more important supplies of the main line had been equipped with softeners. With the coming of the boom, however, and the accompanying expansion of facilities and the purchase of heavier power, many of these plants became of but little value in the locations which they were at that time. Others were found to be entirely too small for the demand which was placed upon them. Between 1923 and 1926, along with the virtual rebuilding of the railroad, there was a corresponding redesign of the water supply facilities and during this time with many of the plants out of service, water softening showed but little economic benefit. Since then, softening methods have been revamped and the derived benefits from the investment are increasing daily.

At the present time, owing to the increased height of locomotive tenders, all of the softeners have been raised. Several have been moved to new locations, two have been taken out of service and three

¹ Presented before the Florida Section meeting, April 4, 1928.

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new and much larger plants of modern types have been erected at the new terminal yards at Jacksonville, New Smyrna and Miami. Supplementing this, naturally soft water supplies not requiring treatment have been developed wherever possible as a result of which policy, only two important water supplies remain on the main line where treatment could be used to advantage and for which treating facilities have not as yet been provided. It is doubtful if there is any railroad district of equal length in the country which is better equipped with soft boiler waters, except in the naturally soft water mountain districts.

Owing to the newness of some of the added facilities, the full benefits as expressed in operating figures cannot yet be given, but enough has been developed already to demonstrate that the expenditure for water improvement has been justified from an economic standpoint. The effect on increased flue mileages has been particularly marked. In 1906, flues were changed every 34,000 miles at a maximum with many sets making less than this. This meant seventeen months service on the average per set of flues. The one softener at Wonderwood and later the other softeners added increased this to 50,000 miles by 1923. During the three years of the boom, averages ranged from 30,000 to 50,000 miles and the records for 1925 and 1926 show only an occasional engine making as high as 60,000 miles and only two in the two years which were able to reach 70,000 miles before shopping.

At present there are four locomotives having flue mileage records of between 120,000 and 130,000 miles and recent interior inspections of these locomotives show that barring accident, the flues should last out the full four-year period before being shopped. The government regulations require shopping at the end of three years, but provide that if the interior of the locomotive boiler is in first class condition, free from scale, leaks and corrosion, an extension of one year may be allowed, although the flues must be renewed after the fourth year in all events. Our mountain type passenger and freight locomotives were purchased in 1925 and 1926 and the extension year will begin to apply in 1928 in consequence of which the boilers are being watched closely.

Moreover, these increased flue records have been made under much more disadvantageous conditions of service than were the older records. The average passenger train in 1906 was 5.9 cars and for the first nine months of 1927 was 11.3 cars an increase of 192 per

cent with the weight and loading of the individual cars also increased. In the same way, the average freight train in 1906 was 13.2 cars loaded and empty where in 1927 it was 60.1 cars, an increase of 455 per cent. Here, also, both tare and gross weight have also increased. The average flue mileage per locomotive per month even two years ago was about 1800 miles with a maximum registered of 4900 miles. During the month of February of this year, three locomotives made more than 10,000 miles each and one of these three has the highest flue mileage of any locomotives on the road. In other words, the performance of this one locomotive during February was equal in ton-miles to the entire life of a locomotive boiler in 1906. It may be added that the performance of that locomotive during March will be higher than in February by two added days' service. It is obvious that where a locomotive averages 400 miles per day, there can be but little allowance for extensive boiler repairs and that the boiler must be and must remain in absolutely first class condition to stand such service for any length of time.

Between May, 1905, and July, 1907, 26 fireboxes were burned out and renewed. At present firebox renewals are almost unknown and there is no estimate as to how long the present fireboxes will last as they show no signs of deterioration whatever. There has not been a single firebox renewal on the Florida East Coast Railway since 1925. Failures from boiler causes other than foaming have also been eliminated. In a special report in 1910 on this subject, George A. Miller, then Superintendent of Motive Power and Machinery, stated: "The number of broken staybolts has decreased to a very large extent. In renewing flues, from one to three bucketsfull of loose scale are now removed where formerly it measured from one to two drayloads. Such troubles as leaky mud-rings, corners, seams, flues, tanks and places around staybolts; all are now running repairs." This condition is even more true at the present time.

Although the results obtained both in increased flue mileages and in reduced boiler repairs have been gratifying, it has been on the problem of foaming that the latest improvements have shown up most remarkably. Foaming is always an adjunct of water treatment because of the increased percentage of alkali salts found in the treated waters over the raw. It has been claimed and partly demonstrated that alkali salts alone will not cause foaming, and that for foaming, mud must be present. But alkali salts will greatly aggravate foaming from mud and mud is impossible to completely eliminate in

locomotive water supplies drawn from many different sources not all of which are treated.

Prior to last June, foaming was prevalent on the Florida East Coast Railway and while there were but few actual failures, the expense in fuel represented by the water blown out was a considerable item. Anti-foam compounds used to correct this condition were of doubtful efficacy for various reasons and owing to the methods in vogue for their use, were themselves a source of foaming trouble. The development of naturally good water supplies has resulted in the elimination of some of our worst waters and the policy of treating all softened waters as low as possible has greatly reduced the mud in the boilers. The combination of both of these has brought foaming trouble within reasonable limits.

At present, no anti-foam compounds of any sort are in use on the railroad. During last summer, some of the local and through passenger runs were combined with the result that some unusually heavy trains made a large number of local stops and created movements which would have been impossible to maintain had foaming been encountered. I doubt if there is a passenger run in the country which is any harder on locomotive boilers than was our Nos. 29 and 30 last summer. This train averaged 14 cars and made 240 miles in seven and one-half hours with an average of 50 stops. The train averaged 32 miles per hour with a stop every 4.8 miles. By way of contrast, the Miamian, the fastest train in the world for the distance run, covers the same distance in six hours and five minutes, averaging 40 miles per hour but making only 5 stops with an average train of 12 cars.

There was, of course, some foaming on this run last summer but during a test on one of the locomotives assigned to this run, a test which covered thirty days, there were only 6 complaints from the engineers regarding foaming. Checks made at that and other times showed that the blowing needed to keep foaming to a minimum averaged 3.75 per cent of the total water used. This is somewhat lower than the average blowing on a number of roads whose published figures indicate an average blowoff of from 5 to 7 per cent.

The endeavor to keep scale to a minimum and at the same time to keep down foaming trouble requires very careful regulation of all chemical charges. In order to obtain completed reactions in the softener tank, a certain amount of excess treatment is required, but

if foaming is to be kept down, this must be no more than is absolutely necessary. To regulate treatment the standard control tests are used both by the chemist and the pumpers. Each water is tested and the charge regulated daily by the pumpers and twice weekly samples are submitted to the laboratory for checking. The pumper is equipped with a small testing outfit for making the soap and acid titration tests and his instructions are plotted on charts which show the change in charge necessary for all probable combinations of these tests. He makes his own changes in charge without waiting for specific instructions. The laboratory checks are further supplemented by frequent visits to the plants for inspection and instruction.

The average hardness of all treated waters on the line at present is about three grains per gallon with no deduction for soap foam, and the endeavor constantly is to reduce this to an average of two grains, which is just about as low as can be expected from the lime-soda process. At three grains, the removal averages 82.5 per cent of all scaling salts. The average treatment cost for chemicals is \$32.50 per million gallons, the average laboratory cost connected with water treatment is \$11.81 per million gallons, making a total cost for chemical maintenance, exclusive of interest, depreciation and repairs, of \$44.31 per million gallons. The net saving effected is somewhat problematical, but one estimate based on the present reduced business made this \$208.30 per million gallons or 473 per cent of the running expenses. This percentage would be reduced considerably were these other items included, but on the other hand will be greatly increased with a larger volume of business, since no plant at present is running at anything like its present capacity. Untreated waters are checked once per month for chlorides, there being but little sulphates in the waters of the east coast.

In addition to the above activities, the chemical department is constantly engaged in allied activities among which may be mentioned the development of anti-corrosion and other compounds and the research necessary to develop naturally soft water supplies. The storing of locomotives during slack seasons is a serious problem so close to salt water and chemical combinations are now being developed to protect boiler sheets and tubes during such times. The laboratory also makes all water analyses in connection with the search for better water supplies and last year was credited with a total of \$1280 for this work at the standard charge of \$20 per analysis.

DISCUSSION

MR. DEMOYA: I would like to ask if there was any material reduction in the fuel costs in the use of water for locomotives.

MR. HOBBS: There has been reduction in fuel of just about 35 per cent, but how much of that is chargeable to improved water softening, and how much to reduced blowing, and whether you can say reduced blowing is from better water supply or not, or how much is due to the new management jacking up the fireman, is a little bit questionable. That is one of the charges that cannot be separated. There is no question but that the reduction in scale itself has reduced the amount of fuel required, but it has been my experience that a careless negro on the throttle-valve can waste more fuel in 10 miles than an inch of scale would if it were on, or would save if it were off. On a long line, when it is spread all over the country, you cannot check these men very closely. Your savings are spread over so many items you cannot separate them accurately.

CHAIRMAN REYNOLDS: What is the average cost of water on these stations?

MR. BOONE: That depends so much on the quantity of water produced, that it is quite variable along the line.

CHAIRMAN REYNOLDS: I thought perhaps you had some figure on the year-round average for all stations.

MR. BOONE: I do not, except for one particular instance. The difference in the cost of water at Jacksonville and Key West brought that to my mind. For the year 1926 the cost of water delivered at Key West in cars, with maintenance, depreciation and interest on investment, amounted to approximately \$6.50 per thousand gallons.

CHAIRMAN REYNOLDS: Was that treated water?

MR. BOONE: Yes.

CHAIRMAN REYNOLDS: You don't know the cost before?

Mr. BOONE: Very little cost before it was hauled, due to the cost in the transportation. The cost is probably 12 or 15 cents per thousand gallons in the storage tanks at Homestead, that is pumping and treating.

CHAIRMAN REYNOLDS: That includes your capital charges?

Mr. BOONE: Yes.

Mr. GIBSON: The reaction that I have gotten out of these two papers is principally one of efficiency. The record as presented us of increased locomotive mileage due to obtaining a better water supply speaks for itself.

The executive of an average manufacturing plant has to buy cheap and sell high. He usually looks at the price of water, first cost, as the big item, paying no regard whatever to whether that water is a satisfactory water or not.

Some twenty years ago I was connected with a contracting firm in the north which put in water supply service for the Pennsylvania Railroad between Pittsburgh and New York. It was during the presidency of Mr. A. J. Cassatt. They had been using water here and there, purchasing it anywhere they could get it, but after we completed the extension of this water works system and obtained a good soft water, I heard their superintendent of motive power at Altoona say that he had never had such a thing so strongly impressed upon him as what a soft water supply meant in the operation of a railroad as had been demonstrated in the use of their new water supply for the last eighteen months. It is not always just the increased mileage of a locomotive that counts, but a thousand and one other things that go to make up the general operation of a large industrial plant. It is comparable to the general health improvement in the city after the installation of a pure, potable supply of water. It is readily understood that the typhoid fever rate is reduced with the new supply over the former supply, but in addition to that, after the installation of the pure water supply, the entire health tone of the consumer or individual is built up. So in manufacturing plants they are able to reduce maintenance on boiler plants, obtaining longer runs, and further reduce the quantities of water in processes and waste in other ways, so that the entire works is benefited.

Another feature I notice in the efforts being made by our railroads

to get a good water supply for steam making purposes. If the Florida East Coast supplied water to individuals in Key West they would probably receive the same complaint that we in the public utility field do; that is, that the cost of water in Jacksonville is only 20 cents per thousand gallons and they cannot see any reason why they should pay \$1.50 for it in Key West.

I recall a conversation with the late Paul Norcross of an argument that he had had with certain citizens in Bermuda. The water supply in Bermuda is entirely rainwater caught in reservoirs and cisterns. He went out to Hamilton to install a water supply for a golf course and he found that the citizens, due to a low rainfall that particular season, were transporting water from New York to Hamilton by boat, and the price was something like \$1.50 per ton delivered at the quays in Hamilton; that is, if my memory serves me right. The people were glad to get the water at this price. Of course, they were very conservative and did not use water as lavishly as we do in the States. But it is always being presented to you that water in some other city in which the customer has lived or has visited is much cheaper than the water in the city in which he now is. He cannot understand it and wants to know why your rates are so much higher than the others. I wish sometimes that these "Doubting Thomases" could read papers such as this one.

I want to mention an instance in our supply at Charleston. Our people had been used to a very soft water supply. Upon the introduction of our Goose Creek supply there was considerable complaint about the hardness. For years we restored the alkalinity after filtration by the use of milk of lime. Some five or six years ago we began to experiment in the laboratory with caustic soda for this purpose. We found that caustic soda would cost delivered somewhere near \$3.90 per 100 pounds as against a cost of 35 cents per 100 pounds for lime. We found also that if we considered that one-fifth of the gross amount of water pumped was used for laundries, house and manufacturing purposes, the cost in soaps and softening compounds for this amount of water would amount to about \$35.00 per day, and the increased cost of treatment of the entire supply using caustic soda instead of lime, would amount to \$15.00 per day, or a net saving to the citizens of the city of \$20.00 per day. While this was not of direct benefit to the water department we deemed it of sufficient importance to warrant the change from lime to caustic soda. We made no mention of this to our consumers, desiring to

note the reaction, if any. The first reaction I obtained was from one of our housewives, when, during a conversation about soaps, she stated that they had made a wonderful improvement in this product since the closing of the war. She stated "during the war period and for sometime you could not get soap that would lather at all, and here for the last few months you can hardly wash the lather off your hands." One of our laundrymen said to me "I do not know what you have done in the change of your treatment of the water at the plant, but you have certainly done something, for during the last few months I have cut out all softening compounds entirely."

The net result of this paper may be summed up in one sentence: "It always pays to get a good water supply."

CHLORO-PHENOL TASTES AND ABNORMAL ABSORPTION OF CHLORINE IN THE CHICAGO WATER SUPPLY¹

By H. H. GERSTEIN²

It is the purpose of this paper to give in detail the history of no doubt the worst condition Chicago has ever experienced in its water supply. This situation occurred in three distinct periods on December 28-29, December 30-31, 1927, and January 7, 1928. In addition to the obnoxious tastes and gross sewage pollution the water had abnormal chlorine absorptive properties, which made ineffective the ordinary amount of chlorine applied to the water for disinfection and would have resulted in a public health hazard had it not been for the prompt and effective measures taken to counteract it.

The southern portion of Chicago, an area having a population of approximately 1,000,000 people, receives its water supply from the 68th and Dunne cribs. The water entering these cribs is subjected to pollution by sewage and industrial wastes from the Calumet River, which is $3\frac{3}{4}$ miles south, the Indiana Harbor Ship Canal, which is $9\frac{1}{4}$ miles southeast, and various sewer outlets along the shore of the lake, as shown in figure 1.

The 68th and Dunne cribs supply three pumping stations, the 68th street, Roseland and Wm. Hale Thompson. The 68th street pumping station, the first on the crib tunnel system, is the first to receive any pollution entering the intakes. The other two stations receive the polluted water from four and one-half to seven hours later, depending upon their pumpage rate.

It is a known fact that there are no fixed currents at the southern end of Lake Michigan, the only currents being those due to the influence of winds. Therefore, pollution of the water entering the 68th and Dunne crib intakes is apt to occur during or after winds from a southerly direction.

¹ Presented before the Illinois Section meeting, March 29, 1928.

² Assistant Sanitary Engineer, Division of Water Safety Control, Bureau of Engineering, Chicago, Ill.

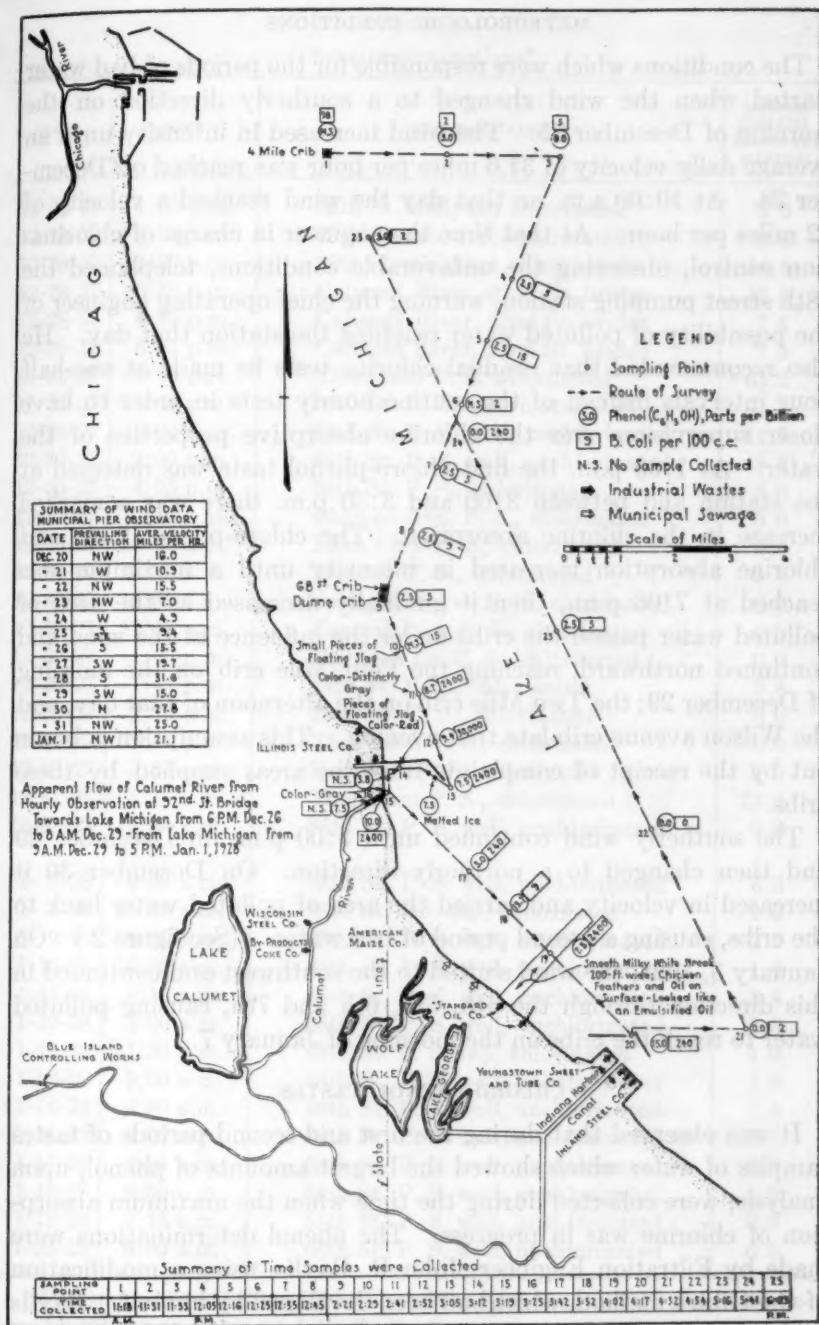


FIG. 1. RESULTS OF SPECIAL SURVEY TO LOCATE POLLUTION CAUSING CHLOROPHENOL TASTES IN WATER—DECEMBER 29, 1927

METEOROLOGIC CONDITIONS

The conditions which were responsible for the periods of bad water started when the wind changed to a southerly direction on the morning of December 25. The wind increased in intensity until an average daily velocity of 31.6 miles per hour was reached on December 28. At 10:00 a.m. on that day the wind reached a velocity of 42 miles per hour. At that time the engineer in charge of chlorination control, observing the unfavorable conditions, telephoned the 68th street pumping station, warning the chief operating engineer of the possibility of polluted water reaching the station that day. He also recommended that residual chlorine tests be made at one-half hour intervals instead of the routine hourly tests in order to have closer supervision over the chlorine absorptive properties of the water. At 1:00 p.m. the first chloro-phenol taste was detected at the station and between 3:00 and 3:30 p.m. there was a marked increase in the chlorine absorption. The chloro-phenol taste and chlorine absorption increased in intensity until a maximum was reached at 7:00 p.m., then it gradually decreased as the area of polluted water passed the cribs under the influence of the wind and continued northward, reaching the Four Mile crib on the morning of December 29; the Two Mile crib on the afternoon of that day, and the Wilson avenue crib late that evening. This assumption is borne out by the receipt of complaints from the areas supplied by these cribs.

The southerly wind continued until 5:00 p.m. on December 29 and then changed to a northerly direction. On December 30 it increased in velocity and carried the area of polluted water back to the cribs, causing a second period of bad water. (See figure 2.) On January 3, 1928, the wind shifted to the southwest and continued in this direction through the 4th, 5th, 6th and 7th, causing polluted water to reach the cribs on the morning of January 7.

CHLORO-PHENOL TASTES

It was observed that during the first and second periods of tastes samples of water which showed the largest amounts of phenol, upon analysis, were collected during the time when the maximum absorption of chlorine was in progress. The phenol determinations were made by Filtration Engineer, John R. Baylis, using a modification of the Gibb's method, which had been developed by himself. Baylis found that five (5) parts per billion of phenol in Lake Michigan water

TABLE 1
Phenol determinations*

DATE	TIME	SOURCE OF SAMPLE	PHENOL C ₆ H ₅ OH (PARTS PER BILLION)
12-28-27	1:00 p.m.	68th St. well, not chlorinated	9.0
12-28-27	3:00 p.m.	68th St. lab. tap, chlorinated	8.8
12-28-27	4:30 p.m.	68th St. well, not chlorinated	54.4
12-28-27	6:35 p.m.	Calumet River, 92nd St. bridge	12.5
12-28-27	6:40 p.m.	Calumet River, 92nd St. bridge	7.5
12-28-27	6:45 p.m.	Calumet River, 92nd St. bridge	7.5
12-28-27	8:30 p.m.	Thompson P. S. chlorinated	63.2
12-28-27	8:45 p.m.	68th St. P. S. chlorinated	51.4
12-29-27	3:00 p.m.	68th St. P. S. well, unchlorinated	11.7
12-30-27	2:00 p.m.	68th St. P. S. well, unchlorinated	8.8
12-30-27	4:25 p.m.	68th St. P. S., chlorinated	5.0
12-30-27	10:15 a.m.	Chicago Ave. P. S., chlorinated	0.0
12-30-27	10:40 a.m.	Lake View P. S., chlorinated	0.0
12-30-27	11:15 a.m.	Mayfair P. S., chlorinated	0.0
12-30-27	11:55 a.m.	Springfield Ave P. S., chlorinated	0.0
12-30-27	12:45 p.m.	Central Park P. S., chlorinated	0.0
12-30-27	1:00 p.m.	Harrison St. P. S., chlorinated	0.0
12-30-27	1:45 p.m.	14th St. P. S., chlorinated	3.8
12-30-27	2:15 p.m.	22nd St. P. S., chlorinated	0.0
12-30-27	2:45 p.m.	Thompson P. S., chlorinated	0.0
12-30-27	3:35 p.m.	Roseland P. S., chlorinated	0.0
12-31-27	5:15 a.m.	Thompson P. S., chlorinated	33.8
12-31-27	10:00 a.m.	68th St. P. S. well, unchlorinated	0.0
1-7-28	9:00 a.m.	68th St. P. S. well, unchlorinated	6.3
1-7-28	10:30 a.m.	68th St. lab. tap, chlorinated	2.0
1-9-28	9:00 a.m.	68th St. P. S. well, unchlorinated	2.9
1-10-28	10:00 a.m.	68th St. P. S. well, unchlorinated	1.0
1-11-28	9:15 a.m.	68th St. P. S. well, unchlorinated	2.4
1-12-28	9:00 a.m.	68th St. P. S. well, unchlorinated	0.0
1-12-28	1:30 p.m.	68th St. P. S. tap, chlorinated	1.0
1-13-28	9:00 a.m.	68th St. P. S. well, unchlorinated	1.0
1-14-28	9:00 a.m.	68th St. P. S. well, unchlorinated	1.5
1-16-28	9:00 a.m.	68th St. P. S. well, unchlorinated	1.5
1-17-28	9:00 a.m.	68th St. P. S. well, unchlorinated	0.0
1-18-28	9:00 a.m.	68th St. P. S. well, unchlorinated	1.0
1-19-28	9:15 a.m.	68th St. P. S. well, unchlorinated	0.0
1-20-28	9:00 a.m.	68th St. P. S. well, unchlorinated	0.5

* Determined by Modified Gibbs Method at Experimental Filtration Laboratory by Filtration Engineer John R. Baylis.

are sufficient to cause tastes when the water is chlorinated. On December 28, at 8:30 p.m., a sample of water collected at the Wm. Hale Thompson pumping station showed 63.2 parts per billion of phenol.

On January 7, samples of water collected at the 68th street pumping station when the taste was at its maximum showed only 6.3 parts per billion of phenol in a sample collected at 9:00 a.m., and 2.0 parts per billion of phenol in a sample collected at 10:30 a.m. At the time these samples were collected the taste in the water was distinctly chloro-phenol and in the opinion of observers it was almost as disagreeable as that of the two previous periods, although the

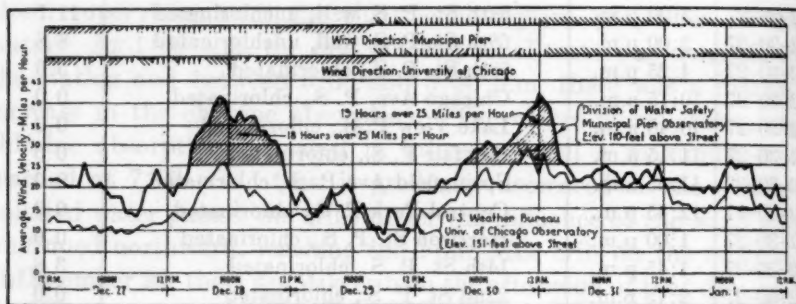


FIG. 2. COMPARATIVE WIND ANALYSES—DECEMBER 27, 1927, TO JANUARY 1, 1928

water did not show a sufficient phenol content to cause such intensity of taste. The probability is that the industrial wastes which polluted the water during this period contained compounds to which the phenol test used by our laboratory was not sensitive. Up to the present time the identity of these compounds has not been determined. Table 1 gives a summary of phenol determinations.

An investigation made by Junior Sanitary Engineer, Carl Speer, Jr., on December 30, at various lake cities south of Chicago, indicates that the taste periods prevailed at these cities even before Chicago experienced them. He found that a chloro-phenol taste of unusual intensity occurred at Gary, Indiana, on December 23 and 24, reaching a maximum on the evening of the 24th. The prevailing wind at that time was from the northwest, which would indicate that the wastes originated at Indiana Harbor. The consensus of opinion of persons interviewed in Hammond, Indiana, indicated that the taste occurred

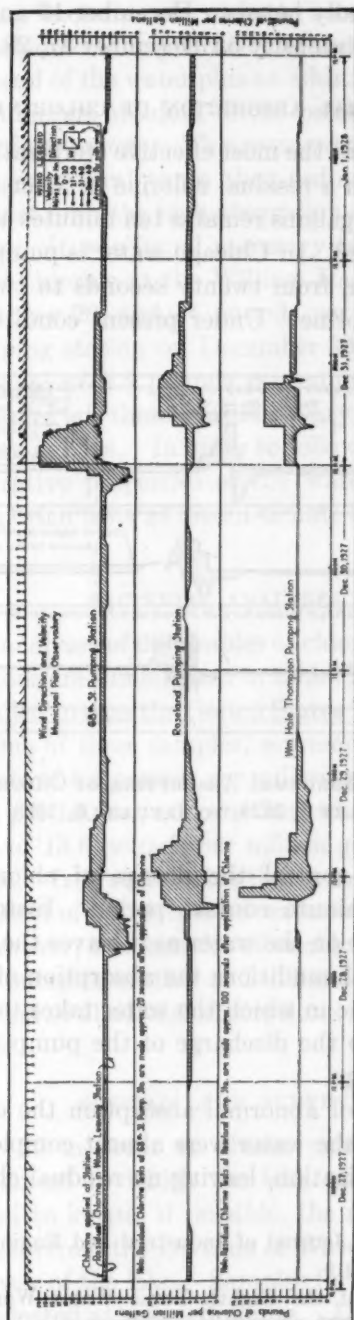


FIG. 3. PERIODS OF ABNORMAL ABSORPTION OF CHLORINE APPLIED. DECEMBER 27, 1927, TO JANUARY 1, 1928

in that city spasmodically between December 19 and December 29, reaching its maximum intensity on December 27, 28 and 29.

ABNORMAL ABSORPTION OF CHLORINE

It has been found that the most effective sterilization of a polluted water is obtained when a residual chlorine between one (1) and two (2) pounds per million gallons remains ten minutes after the chlorine is applied to the water.³ In Chicago water is pumped directly into the distribution system from twenty seconds to two minutes after the application of chlorine. Under present conditions it has been

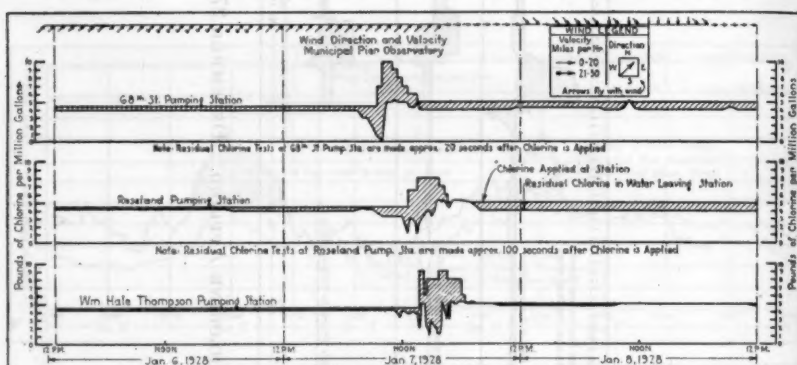


FIG. 4. PERIODS OF ABNORMAL ABSORPTION OF CHLORINE APPLIED.
JANUARY 6, 1928, TO JANUARY 8, 1928

found impractical to control the dosage of chlorine by residual chlorine after a ten-minute contact period. Instead the residual chlorine tests are made on the water as it leaves the discharge of the pumps. Under normal conditions the absorption of chlorine during the short period of time in which the water takes to travel from the point of application to the discharge of the pump varies from 5 to 20 per cent of the dosage.

During the periods of abnormal absorption the ordinary dosages of chlorine applied to the water were almost completely absorbed a few seconds after application, leaving no residual chlorine to do the

³ Wolman and Enslow, Journal of Industrial and Engineering Chemistry, Vol. 11, No. 3, March, 1919.

Enslow, Proceedings of the Eighth Texas Water Works Short School, Bulletin No. 1, page 94, 1926.

work of destroying bacteria. In order to have sufficient chlorine to do this work it required the application of enough chlorine to satisfy the chlorine demand of the water plus an additional amount sufficient to maintain a minimum residual of 2.5 pounds per million gallons at the discharge of the pumps. This required at times the application of chlorine dosages several times that ordinarily used. Figures 3 and 4 show in chart form the high absorption of chlorine at the three pumping stations. It was found necessary to feed 13.6 pounds per million gallons of chlorine at the William Hale Thompson pumping station on December 28, and 14 pounds per million gallons at the 68th street pumping station on December 30, in order to maintain a minimum residual of 2.5 pounds per million gallons. Normally the chlorine dosages at these stations vary between 3.5 and 4.5 pounds per million gallons. In order to follow the rapid fluctuations in chlorine absorptive properties of the water it was necessary to make residual chlorine tests at fifteen-minute intervals, and at times oftener.

BACTERIAL ANALYSES

The results of analyses of 69 samples of chlorinated water collected during these periods are summarized in tables 2 and 3. Only three of the 69 samples failed to pass the United States Treasury standards for a safe water. One of these samples, representing a water to which chlorine at the rate of 8.5 pounds per million gallons had been added, showed 2 *B. coli* per 100 cc., and another, which had chlorine added to it at the rate of 13.6 pounds per million gallons, showed five (5) *B. coli* per 100 cc. It is regrettable that a more complete history of the bacterial content of unchlorinated water during these periods was not obtained; however, two samples of unchlorinated water collected at the Roseland pumping station at 2:33 and 2:53 p.m. on January 7, during the period of abnormal absorption of chlorine, showed 2400 *B. coli* per 100 cc.

SPECIAL LAKE SURVEY

On December 29 in order to obtain more definite information concerning the extent to which the lake waters were polluted by trade wastes, and to locate, if possible, the source of these wastes, a party of engineers from the Division of Water Safety Control made an extensive survey of the lake. Samples for bacterial and chemical analyses were collected at selected points. During the period of the

TABLE 2

Bacterial analyses of samples collected during periods of abnormal chlorine absorption

T = treated water; R = raw water.

SAMPLING POINT	DATE, DECEMBER, 1927	TIME	BACTERIAL COUNT PER CUBIC CENTI- METER		B. COLI PER 100 CC.	RESID- UAL CHLO- RINE (POUNDS PER MILLION GALLON)
			37°C.	20°C.		
68 T-3.....	28	6:10 p.m.	1	0	0	
68 T-2.....	28	6:25 p.m.	2	0	0	
68 T-1.....	28	6:25 p.m.	3	0	0	
68 T-1.....	28	8:05 p.m.	4	1	0	
68 T-1.....	28	8:35 p.m.	1	3	0	
68 R-3.....	28	9:00 p.m.	2,200	270	15	
68 R-3.....	28	9:00 p.m.	3,700	375	38	
Roseland T-1.....	28	8:20 p.m.	2	2	0	0
Roseland T-3.....	28	8:35 p.m.	1	3	0	
Roseland T-2.....	28	8:50 p.m.	1	4	0	
Roseland T-1.....	28	9:05 p.m.	1	0	0	
Roseland T-2.....	28	9:30 p.m.	2	0	0	
Roseland T-2.....	28	9:50 p.m.	3	0	0	
Roseland T-1.....	28	10:15 p.m.	1	1	2	
Thompson T-2.....	28	9:42 p.m.	1	1	0	
Thompson T-4.....	28	9:48 p.m.	1	1	5	
68 T-1.....	30	11:05 p.m.	3	1	0	
68 T-4.....	30	11:05 p.m.	3	2	0	
68 T-2.....	30	11:05 p.m.	2	1	0	
68 T-1.....	30	11:30 p.m.	4	3	0	
68 T-2.....	30	11:30 p.m.	4	0	0	
68 T-4.....	30	11:30 p.m.	3	1	0	
Roseland T-1.....	31	5:00 a.m.	0	1	0	
Roseland T-3.....	31	5:00 a.m.	2		0	
Roseland T-1.....	31	5:15 a.m.	3	0	0	
Roseland T-3.....	31	5:15 a.m.	2	0	0	
Roseland T-3.....	31	5:45 a.m.	2	0	0	
Roseland T-2.....	31	5:45 a.m.	4	0	0	
Roseland T-1.....	31	5:45 a.m.	5	0	0	
Thompson T-2.....	31	5:15 a.m.	3	3	0	
Thompson T-4.....	31	5:15 a.m.	3	2	0	

TABLE 3

Bacterial analyses of samples collected during period of abnormal chlorine absorption, January 7, 1928

T = treated water; R = raw water.

SAMPLING POINT	TIME	BACTERIAL COUNT PER CC.		B. COLI PER 100 CC.	RESID- UAL CHLO- RINE (POUNDS PER MILLION GALLON)
		37°C.	20°C.		
68 T-1.....	10:00 a.m.	1		0	
68 T-2.....	10:00 a.m.	1		0	
68 T-3.....	10:00 a.m.	0		0	
68 T-4.....	10:00 a.m.	0		0	
Exp. Filt. Lab. Tap.....	10:00 a.m.	0		0	
Roseland T-4.....	12:45 p.m.	1	5	0	3+
Roseland T-3.....	12:45 p.m.	1	1	0	3
Roseland T-2.....	12:45 p.m.	0	2	0	3
Roseland T-2.....	1:00 p.m.	0	0	0	3
Roseland T-3.....	1:00 p.m.	1	0	0	3
Roseland T-4.....	1:00 p.m.	2	0	0	3+
Roseland T-2.....	1:15 p.m.	1	2	0	2.5
Roseland T-3.....	1:15 p.m.	1	2	0	3
Roseland T-4.....	1:15 p.m.	0	2	0	3
Roseland T-2.....	1:30 p.m.	1	1	0	2.5
Roseland T-3.....	1:30 p.m.	4	3	0	1
Roseland T-4.....	1:30 p.m.	0	1	0	1
Roseland T-2.....	1:45 p.m.	0	0	0	2.5
Roseland T-3.....	1:45 p.m.	0	1	0	3
Roseland T-4.....	1:45 p.m.	0	0	0	3
Roseland T-2.....	2:00 p.m.	1	2	0	3
Roseland T-3.....	2:00 p.m.	2	2	0	3
Roseland T-4.....	2:00 p.m.	0	0	0	3
Roseland T-2.....	2:15 p.m.	0	0	0	2.5
Roseland T-3.....	2:15 p.m.	0	0	0	4
Roseland T-4.....	2:15 p.m.	0	2	0	4
Roseland R-1.....	2:53 p.m.	275	250	2,400	
Roseland R-1.....	2:33 p.m.	230	600	2,400	
Tap 10848, Wentworth Ave.....	3:30 p.m.	0	0	0	
Tap 11201, Wallace St.....	3:50 p.m.	1	0	2	
Tap 7900, S. State St.....	4:23 p.m.	4	0	0	
Tap 9461, S. Cottage Grove.....	4:15 p.m.	2	3	0	
Thompson T-1.....	1:45 p.m.	0	1	0	4
Thompson T-2.....	1:45 p.m.	1	0	0	2
Thompson T-1.....	2:00 p.m.	0	4	0	5+
Thompson T-2.....	2:00 p.m.	1	0	0	5+
Thompson T-1.....	2:35 p.m.	2	0	0	2
Thompson T-2.....	2:35 p.m.	0	0	0	4+
Thompson T-1.....	2:50 p.m.	1	1	0	1
Thompson T-2.....	2:50 p.m.	0	2	0	5
Thompson T-1.....	3:45 p.m.	26	140	0	1
Thompson T-2.....	3:45 p.m.	0	0	0	4+

survey the wind was from the southwest and of moderate velocity. Figure 1 shows the course followed during the survey and the results of bacterial and chemical analyses of the samples collected.

Samples collected on the course from the 68th and Dunne cribs toward the Calumet Light showed increasing bacterial pollution and phenol content as the Calumet Light was approached. At a point approximately 1 mile northwest of the Calumet Light the phenol content was 9.4 parts per billion and the bacterial content 30,000 *B. coli* per 100 cc. A crude field test indicated that the water at this point had abnormal chlorine absorptive properties.

The water at the mouth of the Calumet River showed 10.0 parts per billion of phenol, and that at the first railroad bridge on the river 7.5 parts per billion of phenol. At the time these samples were collected the river had been flowing away from the lake for approximately five and one-half hours. Previous to this time the river flowed into the lake for a period of sixty-three hours. It is problematic whether the phenol content in the river water originated during the long period of discharge into the lake or whether it was blown towards the mouth of the river from Indiana Harbor by the southwest winds; however, there is evidence that the Calumet River water discharged into the lake on the evening of December 28 contained phenols. Samples collected from the 92nd street bridge at 6:25, 6:30 and 6:35 p.m. showed a phenol content of 12.5, 7.5 and 7.5 parts per billion respectively.

The largest amounts of phenols were found on the course from the mouth of the Calumet River to the Indiana Harbor Light. Opposite the Standard Oil Company's sewers at Whiting, Indiana, a smooth, milky-white area about 200 feet wide and extending approximately 2 miles into the lake from the sewer was sighted. Chicken feathers and sewage débris were scattered on the surface, which appeared to be emulsified oil. Samples collected from this area showed a phenol content of 7.5 parts per billion and a bacterial content of 2400 *B. coli* per 100 cc. The water at the entrance of Indiana Harbor between the two breakwaters showed 15.0 parts per billion of phenol, the highest of any sample collected that day.

There was no phenol in the water 2 miles east of Indiana Harbor. This would indicate that at that time there were no phenol wastes in the lake originating from the Gary district. Had there been any present the southwest winds would have carried the material towards this point.

CONCLUSIONS

1. These conditions were caused by the drifting of water polluted with industrial and sewage wastes from two sources, namely, Calumet River and Indiana Harbor, the latter contributing the major portion.

2. The taste in the third period of bad water was almost as intense as the two previous periods, although the amount of phenol present in the water was below that considered necessary to cause such tastes. The probabilities are that the taste during this period was caused by a different compound.

3. Considering the extent to which the water having abnormal chlorine absorptive properties was bacterially contaminated it was indeed fortunate that the personnel of both the Division of Operation and the Division of Water Safety Control was able to cope with the emergency situation and successfully chlorinate the water. Their prompt action probably prevented a typhoid fever outbreak.

THE SEATTLE WATER SYSTEM¹

BY JOHN LAMB²

Like nearly all things that have reached a degree of magnitude, the Seattle City Water Department came from small beginnings. The first water system was installed in the year 1854, when Henry L. Yesler built a small tank east of the alley in the block where the old city hall used to stand, between Third and Fourth Avenues, Yesler Way and Jefferson Street. From this tank he conducted water in an open V-shaped trough to his mill at the foot of Mill Street (now Yesler Way). An old picture of Seattle, made about the year 1863, shows that this trough was extended northward along the water front to furnish water for boats and local establishments near the water level. At a point higher up on the line a trough was branched off and carried across a trestle to sluice down a hill between First Avenue and the water front to fill in a depression at a point where the Puget Sound Light and Power Plant now have their steam generators. This open trough was afterwards replaced with a wooden pipe, which was made by boring a 2-inch hole in 6-foot sections of a 12-inch log, and connecting these sections with a wooden spigot driven into the ends of the pipe sections. A section of this pipe with the spigot was dug up in March, 1913, when the foundations were being excavated for the L. C. Smith Building. The pipe and spigot were both in a good state of preservation.

Subsequent to this early method of securing water about thirty different private systems were put into operation on the various hills and valleys, both inside and outside of the city limits. These systems were finally abandoned or taken over by the city when its mains reached their vicinity. The most important of these were the Union Water Company's, the Sturtevant, and the Georgetown systems.

The Spring Hill Water Company had been organized in the year

¹ Presented before the Pacific Northwest Section meeting, November 17, 1928.

² Assistant Superintendent, Water Department, Seattle, Wash.

1881, with a capital of \$25,000. At first the company got its water supply from springs on the west side of the first hill, but in 1886 the company built Lake Washington pumping station and began pumping from the lake. When the company began operations in the year 1881 the city established rates by Ordinance No. 253. It is clear that the city proposed, even at that early date, to exercise some control over water rates. Since then numerous ordinances have been passed reducing rates, until now they are less than one-fourth of what they were in early times. It is worthy of note that notwithstanding these reductions the department has been able to carry on through the high price period during and following the war without having recourse to any increase in its charges, and in the meantime showing an average surplus over operating expenses of \$468,445.45 per year.

When the city bought the plant of the Spring Hill Water Company there were three pumps, with a combined capacity of 2,500,000 gallons a day at Lake Washington station. Just twenty days after the purchase the city passed Ordinance No. 1294 providing for the purchase of two pumps with a combined capacity of 2,500,000 gallons per day. The next year, in September, 1891, Ordinance No. 1824 authorized the purchase of an additional pump of 5,000,000 gallons capacity per day, thus raising the pumping capacity of the plant to 10,000,000 gallons per day.

It is worth noting that the failure of the water supply during the great fire of 1889 was a strong argument for a city-owned system, with an adequate quantity of water for such emergencies.

The city paid \$350,000 for the Spring Hill water plant in June, 1890. Since then the plant has been conducted under municipal management.

As early as September, 1888, Robert Moran, then mayor of Seattle, in a letter to the City Council, recommended the investigation of a proposed gravity system. The Council Committee on Fire and Water authorized John G. Scurry, the City Engineer, to investigate and report on the cost of a system. On October 19, 1888, Mr. Scurry made his report, recommending that a supply be obtained from Rock Creek, one of the tributaries of Cedar River. He proposed a 30-inch pipe to bring into the city a supply of 10,000,000 gallons per day; enough to serve a population of 100,000 people. He estimated the cost at \$764,980. The City Council called an election on July 8, 1889, on a proposition to issue bonds in the sum

of \$1,000,000 to build a system; but the amount exceeded the debt limit and the bonds were not issued. The vote stood 1875 for and 51 against. In the meantime Mayor Moran had employed Mr. Benezette Williams, a hydraulic engineer of national reputation, to make surveys and estimates for a system, and Mr. Williams made his first report on November 12, 1889. On February 21, 1890, Mr. Williams filed a report, estimating the cost of the gravity system at \$1,200,793.65, and of the necessary improvements and extensions in the city distribution system at \$535,053.86.

In a letter to the City Council on August 11, 1890, Mr. Williams said, "There is no alternative consistent with the safety of the city, but to enter at an early date upon the building of the Cedar River Works as proposed, or to definitely abandon this plan and begin upon the construction of entirely new pumping works, force mains, and reservoirs, to supply fully both high and low service districts from Lake Washington." It will be noticed that in Mr. Williams' report the use of Rock Creek is abandoned, and the headworks finally located in its present position in Section 19, Township 22, N. R. 7 E. W. M.

There is an amusing story in connection with the early discussions of the Cedar River pipe line. When Mr. Whitworth, of the engineering firm of Thomson and Whitworth, suggested that it would be necessary to go several miles up Cedar River in order to secure sufficient elevation to deliver water in adequate quantity to the reservoirs by gravity, a local engineer (so the story goes) declared that no such proceeding would be necessary; that if an open spout were lowered into Cedar River at Renton the tremendous force of the current would force the water up into the reservoirs at Seattle.

The growth of the city during thirty-nine years is indicated in some degree by a comparison of the vote cast in 1889 with that cast in 1927. The total vote on the Cedar River proposition was 1879. The vote in 1927 was 100,798. In 1889 women had the voting privilege, and actually did vote in that year, so the comparison is legitimate.

The contract for the construction of Pipe Line No. 1 was let April 19, 1899. The work was executed under the direction of R. H. Thomson, City Engineer. Water was delivered in the city in January, 1901. The line will deliver 22,500,000 gallons per day. Within five years, however, this supply had become insufficient and another pipe line had to be built. The first pipe line, with the

necessary intake and controlling works, reservoirs, etc. cost \$1,250,000.

A contract for Pipe Line No. 2 was let on August 15, 1908, and water was delivered in the city reservoirs on June 21, 1909. This pipe line delivers 44,769,000 gallons per day. The cost was \$2,250,000.

The two pipe lines give the city a supply of 67,269,000 gallons per day.

During the past three years this supply would have been insufficient on some hot days in summer had it not been for the building of Pipe Line No. 3 from Ginger Creek to the city, which enables the delivery to be increased about 10,000,000 gallons daily, without drawing from Lake Youngs.

LAKE YOUNGS SOURCE

The proposition to use Lake Youngs as an impounding basin had been discussed at various times. It was evident that if this lake could be raised 20 feet a volume of water could be accumulated during the winter months sufficient to tide over the summer period of greatest consumption for some years to come. Two dams were built, one at the south end and one at the northeast end of the lake, to prevent outflow when the water level was raised, and a tunnel 8 feet in diameter and over 2 miles long was constructed from the lake to a controlling works at Molasses Creek. All three of the pipe lines are connected with these controlling works, and are now available to convey water from Lake Youngs to the city, making the possible delivery to the city 117,500,000 gallons per day.

The contract for the construction of Pipe Line No. 3 was let on April 4, 1922, for \$1,468,602.50. This bid, however, did not cover the cost of the backfilling and pavement repairs. These costs aggregated approximately \$500,000, making the total cost of the work substantially \$2,000,000. The line consists of a 66-inch steel riveted pipe 15 miles long, which is estimated to have a capacity of 50,000,000 gallons per day. This line, however, could not be made fully available until the tunnel from Lake Youngs to Molasses Creek and the controlling works at the latter point were constructed. A contract for this work was let to Jahn & Bressi, on February 13, 1924, for the sum of \$1,210,759. Before the work was finished defects began to appear in the tunnel lining. A difference arose as to who was responsible for these failures, whether the contractor or the

city. Finally, the Board of Public Works took the construction out of the hands of Jahn & Bressi and let a contract for finishing the job to J. M. Clapp. When this contract was completed and paid for the cost of the entire work, which included the intake, controlling works, and 6,200 feet of 66-inch steel pipe between the controlling works and the end of the pipe previously installed from Ginger Creek to the city, aggregated approximately \$1,625,000.

The two wooden pipe lines above Lake Youngs are capable of bringing into the lake about 74,500,000 gallons per day, about 8,000,000 gallons more than they could deliver into the city reservoir. While this quantity, under ordinary circumstances, would be sufficient to supply the city, except for a short time in summer, yet if a condition should arise (which is wholly improbable) that Lake Youngs should be drawn down to its limit, and a spell of very dry, hot weather should supervene, there would be a shortage of the supply with our present population. Of course this condition would be aggravated if the population were much greater.

CEDAR LAKE DEVELOPMENT

In order to get an increased supply into Lake Youngs it is intended to build a conduit from a point at or near the present headworks on Cedar River to Lake Youngs, a distance of $8\frac{1}{2}$ miles, and having a capacity of 300,000,000 gallons per day. The survey for this line has been made, and a right of way secured. It will doubtless be built in the near future.

The Pacific States Lumber Company of Tacoma, to whom a contract was let in the year 1917, for logging the city timber in the watershed, have removed the timber from an area of eleven square miles. A part of this area will reforest itself, but owing to the fires that have swept across the watershed from time to time, most of the land will have to be planted. A camp has been established and some progress has been made in setting out new seedlings. It is expected that within a few years all the denuded lands, not naturally reforesting, will be replanted and in process of reforestation. This work will doubtless be extended to the lands which are now covered with Northern Pacific Railway timber, as soon as they are logged; the lands, exclusive of the timber, having been deeded to the city by the railway company. The area of these lands is 11,997.92 acres, equivalent to 18.75 square miles. The deed to these lands was accepted by the City Council on September 4, 1924.

The national government has about 34.5 square miles of area in the watershed, a considerable portion of which is in the higher altitudes, and almost devoid of merchantable timber. The available timber on these lands may be sold and logged off, in which case, no doubt, some reforestation will become necessary. The total area of the drainage basin is about 140 square miles.

The original elevation of Cedar Lake was 1,530 feet. The building of the crib dam in the year 1905, at a point about $\frac{1}{2}$ mile below the outlet, raised the lake level to 1,548 feet. Subsequently, in the year 1915, when the masonry dam was completed, at a point about 2 miles below the lake, the spillway in the new dam had an elevation of 1,555 feet. This elevation can be increased by flash boards up to 1,560.5 feet, which is 30.5 feet above the original elevation of the lake. During flood periods the water has sometimes been more than 6 feet above the top of the flash boards. While the construction of these dams was primarily intended to secure water for hydro-electric power, yet in view of the fact that during very dry seasons the run-off from Cedar Lake was very low in the original river bed, wholly insufficient for the city's needs, enough seepage took place from the bed of the lake to make a considerable stream just above Barneston, 6 miles below the masonry dam, before the flow was augmented by the waters of Taylor Creek, which comes into Cedar River at Barneston. It is a significant and interesting fact that an area of 8 square miles just above Barneston supplies more water to Cedar River during the dry season than the whole area above the masonry dam, thus showing clearly that the impoundage of water by the dam creates an underground reservoir, far greater than that which could be secured from the lake during the dry season, had no dams been constructed.

It is also worthy of note that this underground flow is all filtered water, having come almost entirely through 7 miles of morain before being again poured into Cedar River.

DISTRIBUTION SYSTEM

For distribution purposes the city is divided into three zones. The lower zone is all that section of the city below elevation 225. This is supplied by gravity from reservoirs having an elevation of 316 feet. The intermediate zone is all that portion of the city having an elevation between 225 and 325. This section is supplied

by gravity from reservoirs having an elevation of 420 feet. The high service zone includes all that section of the city having an elevation higher than 325 feet. This district is supplied by pumping from the reservoirs, and in some cases directly from the mains into the standpipes, from which the water is conveyed by gravity to consumers. These standpipes have various elevations.

The elevation of the water at the intake at Landsburg is 535 feet. The pipe lines deliver by gravity from that elevation to the reservoirs that have an elevation of 420 feet. There is, therefore, a head on the pipe lines of 115 feet. In the case of Lake Youngs, however, which at its highest elevation, will have an altitude of 488 feet, the head will be only 68 feet, but the new pipe line from Lake Youngs has a cross-sectional area of 23.76 square feet as against an area of 9.62 square feet in pipe line No. 1, and 12.56 feet in pipe line No. 2. The new line has, therefore, a greater area than both the old ones together, and will deliver under the lower head 50,000,000 gallons per day.

SUMMARY

I present a brief summary of the present physical equipment of the plant:

The dam, intake, and controlling works at Landsburg, 28 miles from the city.

A 42-inch wooden stave pipe line from the headworks to the city.

Four 48-inch wooden stave pipe line from the headworks to the city.

A 66-inch steel pipe line from Molasses Creek to the city.

An intake at Lake Youngs, and an 8-foot tunnel from Lake Youngs to Molasses Creek 11,300 feet long.

Controlling works at Molasses Creek.

Six concrete reservoirs in the city with a combined capacity of 266,000,000 gallons.

Eight steel standpipes with a combined capacity of 6,734,000 gallons.

Three wooden standpipes with a combined capacity of 150,000 gallons.

Total storage in the city of 272,884,000 gallons.

Eight pumping stations with a combined capacity of 35,000,000 gallons per day.

Mileage of supply mains.....	79.63
Mileage of distributing mains.....	837.547
Total mileage.....	917.177
Number of hydrants.....	8,591
Number of gate valves.....	7,436
Number of meters.....	74,243
Consumption per capita per day.....	104 gals.
New services installed in 1927.....	4,215

The sales of timber from the watershed up to January 1, 1928, was 260,340,255 feet board measure, for which the city has received \$564,805.37. This money is put into a reserve fund to pay the bonds issued for the purchase of the land and timber. The receipts from the sale of timber will doubtless amount to enough to pay for the cost of the watershed.

The charge for tapping mains is paid by the consumer. Fifteen dollars is the price for a $\frac{3}{4}$ -inch tap and \$18.00 for a 1-inch tap. For larger sizes, and on paved streets the actual cost of the work is charged. The city supplies the meters without cost to the consumer.

The rates for water are as follows:

For 500 cubic feet or less used in any one month 50 cents.

For any quantity above 500 cubic feet used in any one month 6 cents per hundred cubic feet, except that for motors, elevators, laundries and factories, the rate for all quantities used in any one month over 30,000 cubic feet is 4 cents per hundred cubic feet.

A few words about the financial status of the plant.

When the city brought the plant in the year 1890 it was presumably worth the purchase price of \$350,000, although the Spring Hill Company valued it at \$840,000; but offered to sell for \$600,000. Seven years later in 1897, the plant was appraised at \$950,000. The building of pipe line No. 1 added \$1,250,000 to this value in 1901, and the building of pipe line No. 2 in 1909 added \$2,250,000 more. In the meantime extensive additions had been made to the distribution system in the city until, in the year 1914, the valuation was \$10,217,859.65. In the year 1919 an adjustment was made for depreciation, which reduced the book value nearly \$1,000,000, so that in the year 1920 the book value showed only \$12,082,780.95. This slow growth in value was also due to the let up in new construction during the war. At the close of the year 1927, after deducting \$5,384,242.97 for depreciation, the plant showed a net value of \$20,120,188.70.

Since the year 1910 the department has issued bonds amounting to \$12,936,980, and has redeemed \$6,688,948.80, leaving an unredeemed issue on January 1, 1928, of \$6,248,031.20. To meet these bonds when they become due there is now accumulated a fund of \$1,100,000. These funds are invested in interest bearing securities issued by various states, counties and cities, bearing from $4\frac{1}{2}$ to 6 per cent interest.

The operating income for the year 1927 was \$1,704,522.42. The expense \$1,196,993.80, leaving a net income of \$507,528.62. In the expense account there is included a depreciation of \$444,814.17, and interest on the bonded indebtedness. The operating expense proper was \$486,857.00.

For the year 1927 we estimate an average daily consumption of 46,121,383 gallons, 39,121,383 of which was registered by meters. The city is 100 per cent metered. The department is allowed \$94,883.63 for the use of water for parks, streets and sewers, and fire purposes. These services are not metered, which accounts for the difference between the metered consumption and the total consumption.

It has always been the custom to charge against the water fund all that portion of the expense of installing large feed mains in the city over and above the cost of installing a main of sufficient capacity to supply the needs of the buildings on the street where it was located; in other words, a distinction was made between feed mains and local distribution mains, the extra cost of the former being paid from the water fund.

All mains in residence districts over 8 inches in diameter, and all mains in the business district over 12 inches in diameter, are classed as feed mains. This permitted the assessments against abutting property to be more evenly distributed in accordance with its local needs, but threw an additional cost for construction on the water fund. It is clear that under this plan the property assessments do not cover the entire cost of the mains in the city; a large portion of this cost being drawn from the water fund.

CONSTRUCTION OF A GUNITED STEEL AND CENTRIFUGALLY CAST CONCRETE PIPE LINE¹

BY E. A. ROWE²

The Laguna Beach pipe line has now been in operation for over one year. While this period of time is not adequate to reach definite conclusions as to the merits of the types of pipe used, a recent examination of the entire line made by the engineers in charge of the work showed it to be in excellent condition and indicated that their expectations at the time the line was installed would be justified as time went on. In as much as this pipe line was constructed of pipes heretofore unused in California, it aroused the interest of many water works men and during construction was visited by many members of the engineering profession. As a complete description of the design and construction of this conduit has never been presented to the water works profession, I have been requested to present this paper to the annual convention of the American Water Works Association with the hope that it may be of some interest.

Laguna Beach is located on the coast of Orange County about 35 miles south of Los Angeles Harbor. It is one of the oldest and most delightful beach towns of California. The coast at this point is particularly beautiful and has many times been painted by the leading artists of the country. In 1926 it had a permanent population of approximately 1500. During the summer season the population increases to more than 6000. The water supply for this community prior to the installation of the works described was obtained from wells located in the small canyons back of the town. The water from these wells was poor in quality and scant in quantity. As a result of the past group of dry years in Southern California this source of supply practically failed and most of the water consumed in the district was brought in, in bottles or tank wagon.

To relieve the situation a water district was formed under the

¹ Presented before the San Francisco Convention, June 13, 1928.

² Of Engineering Offices, J. B. Lippincott, Consulting Engineer, Los Angeles, Calif.

County Water District Act and the Engineering Offices of J. B. Lippincott were employed to prepare plans and estimates for bringing in a new water supply and the construction of an adequate distribution system. It is interesting to know that the election for the organization of the district was unanimous. When the bond election was submitted to the voters it was also unanimous. The total area within the boundaries of the district is approximately 1450 acres. A bond issue of \$600,000 was voted for the construction of the necessary works. This represents a debt of \$400.00 per acre for the lands of the district and at the time of the election approximately \$400.00 per capita.

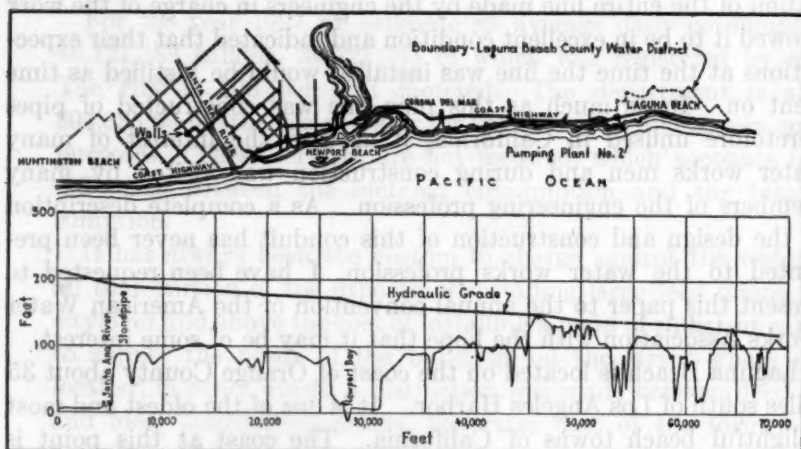


FIG. 1. General plan and profile of the Laguna Beach pipe line

Investigations showed that the only available source of water supply was from the ground waters of the coastal plain largely replenished by the Santa Ana River. One hundred and twenty acres of water bearing land were purchased by the district for the necessary wells. These wells are located about 13 miles northerly up the coast from Laguna Beach. To make this water available for the district it was necessary to construct a pipe line approximately 70,000 feet in length to the westerly boundary of the district and to install pumping equipment for lifting the water from the wells about 175 feet through this pipe line.

The location of this line and a profile of the same are shown on figure 1. Between Newport Bay and the City of Laguna Beach the

line parallels the State Highway from Los Angeles to San Diego and passes through a strip of unusually attractive coastal lands belonging to the Irvine Company. These lands in the near future will undoubtedly be developed for residential purposes. They had no adequate water supply immediately available. When Mr. Irvine was approached by the directors of the district to secure the necessary right of way for their conduit over these lands he suggested that the pipe line be constructed adequate in size to care for not only the Laguna Beach County Water District but his lands fronting the coast. Mr. Irvine agreed to contribute to the cost of the line on the basis of the carrying capacity allotted to him as well as furnish the right of way free of cost. As such an arrangement would result in a substantial saving to the district a contract was entered into between the district and the Irvine Company whereby this line was built and a portion of its carrying capacity allotted to the Irvine Company. The Company paid over half the cost of the entire line for approximately half the capacity. The Company is to develop their own water independent of the water district for the service of their lands. The operation and maintenance of the line is vested entirely in the Laguna Beach County Water District, the cost thereof to be prorated between the two parties.

SELECTION OF TYPE OF CONDUIT

The selection of the proper type of conduit was given particular consideration. Economic studies were made for various routes, assuming its construction of practically all the various types of pipe then in use in California. These studies were made by determining the total cost of the line of various sizes and kinds of pipe for a term of years, the cost including interest, depreciation, maintenance and operation, including pumping expenses. Consideration was given to the length of life of the various kinds of pipe and to their coefficient of friction. The line has a maximum capacity of 15 second feet for over 75 per cent of its length, reducing to 5 second feet at its terminus. The controlling elevation is located about two-thirds of the distance from the wells, the elevation at this point being approximately 150 feet higher. That portion of the line from the wells to the high point will be a force main subject to water hammer. From this point the water flows by gravity to a reservoir at its terminus on the westerly side of the Laguna Beach District. Air chambers are to be installed at the pumping plants so that the maximum head on the force main

including water hammer will be in the neighborhood of 250 feet and the maximum head on the gravity line 125 feet.

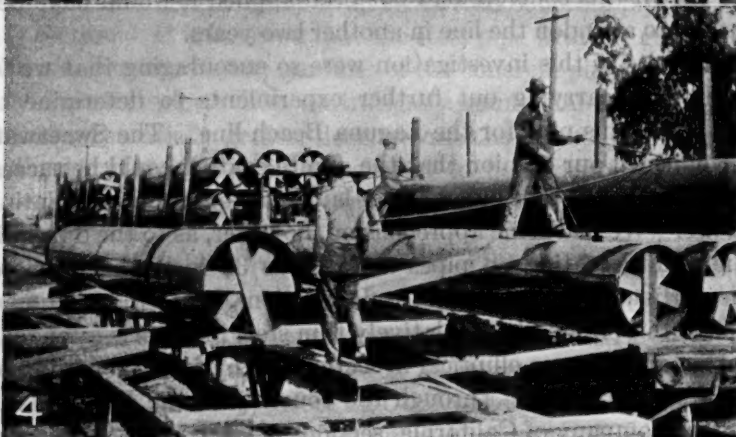
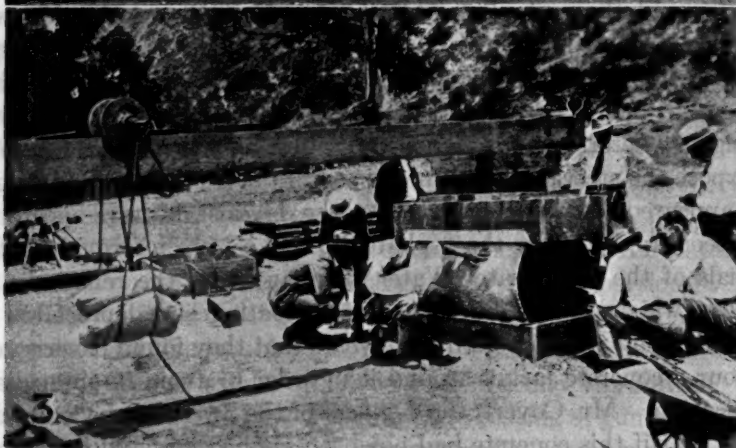
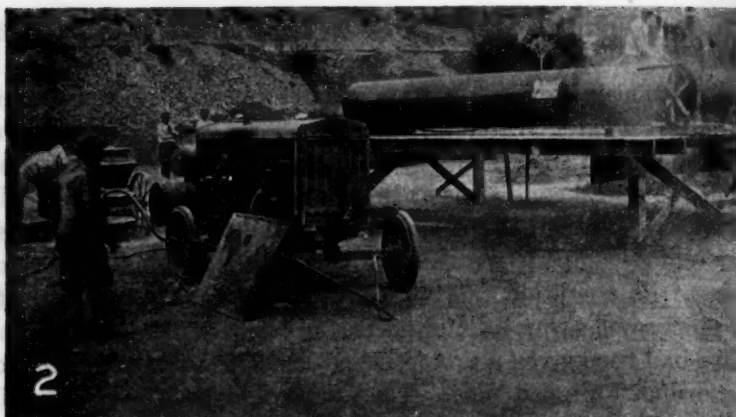
The line for practically its entire length passes through sedimentary soils which experience has shown to be particularly severe in their corrosive action on steel pipe. In view of the heavy initial cost of this line every effort was made to secure one that would have a relatively long life as well as adequate strength to withstand the pressures obtaining. The most satisfactory type of pipe to meet these requirements is undoubtedly cast iron. Our estimates showed that the cost of building this line of cast iron, however, was beyond the financial resources of the district. The two types of pipe most generally used in California for such construction are either of steel or reinforced concrete. Both types have their advantages and disadvantages. The steel pipe has adequate strength, but in these sedimentary soils has a relatively short life. Reinforced concrete pipe as manufactured up to the time of the construction of this line had a long life but was lacking in strength. Previous to this time it had not been successfully used on a large scale for heads over 125 feet. Owing to the many steep syphons existing in the gravity portion of the line the type of joint in general use in reinforced concrete pipe was expected to give trouble. As a result of intensive investigations and experiments as will be described later, the line was built of electrically welded steel pipe having a protective coating of gunite for the force main and a centrifugally spun reinforced concrete pipe for the gravity section. It is believed that the steel pipe with the gunite coating will combine the lasting qualities of the concrete pipe and the strength of the steel pipe. The centrifugally spun reinforced concrete pipe has substantially greater density than the ordinary poured pipe and the type of joint used is believed to be superior to the methods used in joining the poured pipe.

GUNITE PROTECTION OF STEEL PIPE

In numerous localities in Southern California steel pipe which had begun to show wear was exposed and a concrete jacket poured around the pipe. While this work has resulted in an increase in its life, it has been expensive. Mr. Lippincott and the writer had long been considering the possibility of protecting steel pipe with gunite. Investigations were made as to the feasibility of protecting the pipe in this manner and it was found that the late J. D. Schuyler, an eminent California engineer, had had the same idea some fifteen

years previously. In connection with some work he was doing for the Sweetwater Water Company in San Diego County he had had some riveted steel pipe coated with gunite and installed in their system. The soil conditions at that point are particularly severe on steel pipe. Through the cooperation of the officials of the Sweetwater Water Company we had this line exposed and made an examination of its condition. It was built of 12-inch 14-gauge riveted steel pipe, some several thousand feet in length. About 200 feet of the line had been given a protective coating of gunite, the remainder being ordinary dipped pipe. The gunite had been applied in Los Angeles and the pipe shipped by rail to San Diego where it was installed. The coating was about 0.5 inch in thickness, reinforced with 1-inch mesh poultry netting. When examined it was found that the gunite was in excellent condition, free from cracks and showed no sign of deterioration. An opening was cut through the gunite to expose the steel to determine its condition. The steel was bright and appeared to be as good as it was the day installed. This gunite had been applied over the asphalt dip. We were informed by the officials of the Sweetwater Water Company that the remainder of the line which did not have the gunite coating had depreciated to such an extent after a period of 13 years that they found it necessary to pour a concrete jacket around it in order to avoid its immediate duplication. Mr. Covert, the engineer of the Sweetwater Company, states that if this concrete had not been applied it would have been necessary to abandon the line in another two years.

The results of this investigation were so encouraging that we felt warranted in carrying out further experiments to determine the feasibility of this pipe for the Laguna Beach line. The Sweetwater pipe confirmed our opinion that the gunite coating could be successfully applied to the pipe before it was laid and would add substantially to its life. We had some apprehension, however, as to the durability of the gunite coating on pipes as large as 30 inches in diameter, particularly under external load and pulsations due to water hammer. A pipe of this size made of relatively thin steel plates has a tendency to flatten and become elliptical in section when empty, rounding out under water pressure. Through the courtesy of the Western Pipe and Steel Company of California, sections of electrically welded steel pipe 30 inches in diameter and of varying thickness were manufactured for the district for experimental purposes. A yard was provided in Laguna Beach and these sections of pipe were given various



FIGS. 2 TO 4

FIG. 2. Guniting experimental sections of steel pipe.

FIG. 3. Testing experimental sections of guniting steel pipe for external load.

FIG. 4. Steel pipe arriving in yard at Costa Mesa.

thicknesses of guniting coating, reinforced in various manners. The equipment and labor necessary to carry on these investigations were furnished free of charge by the Cement Gun Construction Company of California. Mr. Vern Case of that company coöperated throughout the experiments with the writer and the other engineers. These experimental sections after being thoroughly cured were tested for external load in a machine as shown in figures 2, 3 and 4. These tests were made to determine the deflection the pipe would stand without cracking the guniting as well as its durability under ordinary conditions of handling, the proper thickness of steel and guniting to be used, the proper type of reinforcing and the most satisfactory mix. The results obtained from this test, while interesting and of value in determining the proper thickness of steel and guniting, were not conclusive as to the external load the pipe could stand owing to the relatively short sections tested and the methods of loading. They showed that the thickness of the steel plates was of greater importance than the thickness of the guniting coating in order to prevent cracking. For a 30-inch line it was decided to use $\frac{3}{16}$ -inch plates with a $\frac{3}{4}$ -inch coating of guniting having a mix of one of cement to five of sand. This resulted in a one to three mix on the pipe. The reinforcing decided upon was a galvanized, electrically welded fabric, 2-inch by 4-inch mesh of 14 gauge wire.

As a further test, a section of 24 feet in length was gunited and buried in a trench with 6 feet of cover. This pipe was later removed and showed practically no cracking. This section was then given rather severe handling without damage to the guniting. The experiments demonstrated the importance of proper curing and the necessity of bracing the pipe in the interior to bring it to a true circle until the guniting had cured, at which time the braces could be removed and the pipe handled without damaging the protective coating. Data were also obtained upon which to base an estimate of the cost of doing this work. It is interesting to note that the cost as actually determined over the entire job was practically as originally estimated.

INVESTIGATION OF CENTRIFUGALLY SPUN, REINFORCED CONCRETE PIPE

For the gravity portion of the line investigations and experiments were made through the courtesy of the Western Concrete Pipe Company of centrifugally spun, reinforced concrete pipe. Pipe manufactured by this process had been used to some extent in the east but to our knowledge none had been installed on the west

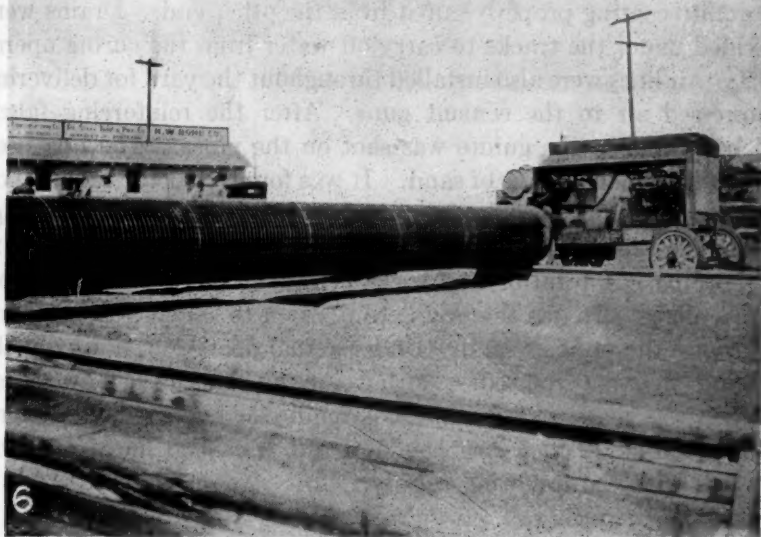
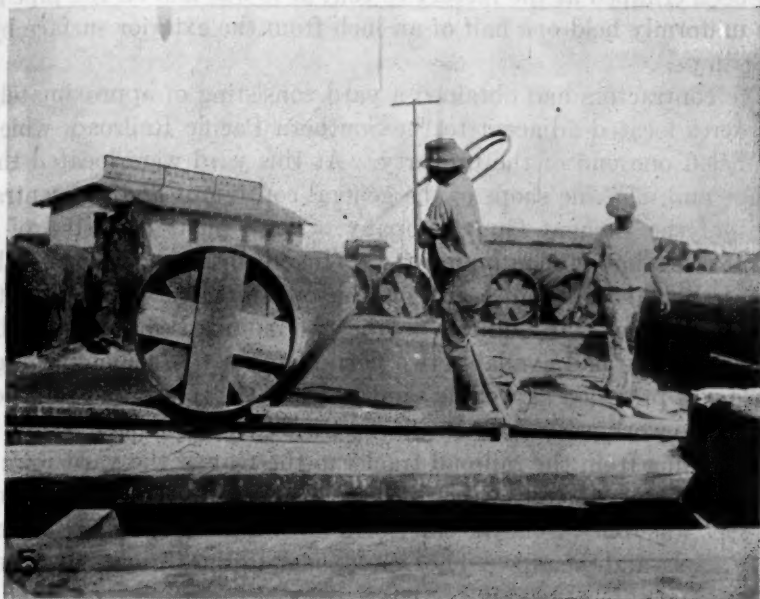
coast. It had been extensively used in Australia and South Africa. A search was made of all available literature dealing with this pipe and the Western Concrete Pipe Company installed apparatus for manufacturing it under the so-called "Hume" process. Experiments were made at their plant under the direction of the engineers of the district to determine the proper mix, type of reinforcement and time and rate of spinning. The experimental sections were tested under internal pressure with very satisfactory results which resulted in specifying this type of pipe for the gravity portion of the line.

Specifications were drawn and bids received which resulted in the award of the general contract for the entire line to the H. W. Rohl Company of San Francisco. The steel pipe was manufactured by the Steel Pipe and Tank Company of Berkeley. The gunite coating was applied by the Cement Gun Construction Company of California and the reinforced concrete pipe was manufactured and laid by the Western Concrete Pipe Company of Los Angeles.

CONSTRUCTION OF FORCE MAIN

The steel pipe was manufactured at the factory in sections 32 feet in length. Each section was made up of two plates. The plates were rolled and the longitudinal seam was automatic electric butt weld. These two cylinders, or "cans", were joined by an automatic electric lap weld. The pipe was made of inside and outside courses, the minimum internal diameter being 30 inches. After the pipes had been welded into sections 32 feet in length they were tested under an internal pressure of 150 pounds per square inch and all leaks or sweats repaired.

After being tested it was pre-heated and vertically dipped with petrolastic pipe dip. The ends of each section were protected so that they were not covered with dip for the last six inches. The pipe was shipped from Berkeley to a yard located at Costa Mesa, near Newport Beach, where it was unloaded and all places where the dip had been damaged were repaired. The interior bracing was then placed in the pipe to bring it to a true circle. Three sets of braces were put in each 32 foot section, one in the center and one at each end. The character of this bracing is shown in figures 5 and 6. After the bracing had been installed the reinforcing fabric was applied to the outside of the pipe. This consisted of 14-gauge galvanized electric welded fabric. The roundabout wires were 2-inch centers and the longitudinal wires 4-inch centers. This fabric



FIGS. 5 AND 6

FIG. 5. Guniting pipe in yard. Note bracing in interior of pipe.

FIG. 6. Reinforcing in place and pipe on tracks in contractors yard.

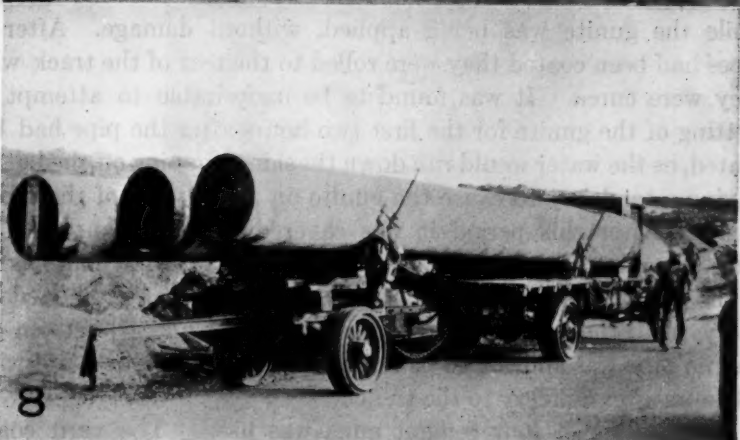
had been crimped at the factory so that as it was laid on the pipe it was uniformly held one half of an inch from the exterior surface by the crimps.

The contractors had obtained a yard consisting of approximately five acres located adjacent to the Southern Pacific Railroad, which paralleled one end of the property. At this yard were located the garage and machine shops of the general contractor and the central plant of the Cement Gun Company. Their plant consisted of a compressor house containing two Ingersoll-Rand permanently mounted 300-cubic-foot air compressors directly connected to gasoline engines. In addition to the two mounted compressors the contractor also had available two portable ones. A cement storage house was provided as well as sand bunkers. Cement and sand for the gunite work was mixed dry at a central mixing plant.

Extending from the railroad tracks to the rear of the yard were a number of wooden tracks about 31 feet centers to center upon which the pipe was rolled from the cars. All of the yard work was done on these tracks and the pipe did not leave them until the gunite had been applied and cured. As the plant was operated, pipe was continually being received at one end of the track and delivered to trucks with the gunite coating properly cured from the other end. Drains were provided under the tracks to carry off water from the curing operations. Air lines were also installed throughout the yard for delivering compressed air to the cement guns. After the reinforcing fabric had been applied the gunite was shot on the pipes. The mix used was one of cement to five of sand. It was found that the rebound on pipe work was considerably more than on flat work, such as buildings or canal and reservoir linings. A 1:5 mix at the gun would give 1:3 on the pipe. A total of 14.4 sacks of cement were used per cubic yard in place. It was the original intention to salvage the rebound and re-use the same as sand. Under actual operation, however, the rebound was not re-used. During the progress of the work an analysis was made of the materials required and percentage of rebound for one 32 foot length of pipe, of which 30 lineal feet was gunited, with the following results:

Material put in mixer, in cubic feet

Cement.....	7
Sand.....	35
Total.....	42



FIGS. 7 TO 9

Fig. 7. Large special angles manufactured and guniting in yard.

Fig. 8. Special truck and dolly used in transporting guniting steel pipe to trench.

Fig. 9. Unloading at trench.

After mixing the volume was 38.7 cubic feet. Rebound during shooting was collected on a canvas and when measured was 14.7 cubic feet. Assuming all rebound was sand, then total rebound equals 42 per cent of sand measured loose. Net material in cubic feet shot on above assumption was:

Cement.....	7
Sand.....	20.3

Resulting mix on pipe = 1:3.

It was found that the pipes could be rolled, if handled carefully, while the gunite was being applied, without damage. After the pipes had been coated they were rolled to the rear of the track where they were cured. It was found to be undesirable to attempt any wetting of the gunite for the first two hours after the pipe had been coated, as the water would run down the side, dropping off the bottom, having a tendency to cause the gunite on the bottom of the pipe to slump. After this period it was covered with wet burlap. This burlap was kept wet continuously during the daylight hours as long as the pipe was in the yard. No pipe was allowed to be removed from the yard to the trench until it had been cured for at least ten days and no pipe was allowed to be removed that could not be laid within 48 hours after delivery to the trench.

A maximum of four cement guns was used. The yard coating extended to within 12 inches of the ends of the pipe, the reinforcing extending 6 inches beyond. All angles more than 5 degrees required for the laying of the line were manufactured and gunited in the yard. These angles were cut from the full length sections and were in most cases gas welded together. Figure 7 gives some idea as to the size of these fittings.

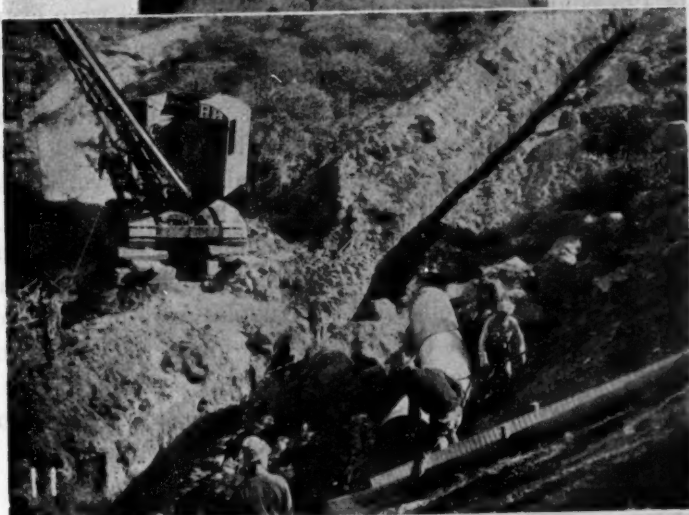
After the pipe had been cured in the yard it was loaded on a specially designed truck and hauled to the trench side. At the delivery end of the tracks in the yard a ramp was constructed for rolling the pipe

FIGS. 10 TO 12

FIG. 10. Laying 30-inch gunited steel pipe in trench. Welder is making a "tack" weld for hinging pipe over preceding section for lap welding field joint. Note manhole for work on interior of pipe.

FIG. 11. Gunited steel pipe was laid in many rough canyons such as this without damage to the coating.

FIG. 12. Portable outfit used in guniting field joints.



onto the trucks. Owing to the length of the sections it was necessary to haul them with truck and dolly as shown in figures 8 and 9. In order to prevent damage to the gunite coating, the bolsters of the truck and dolly were provided with a rubber seat. Three sections of pipe were carried at a time and upon delivery at trench side the pipe was carefully unloaded from the truck and snubbed to the ground on skids.

The pipe was laid in a trench 39 inches in width in the bottom of which at least 4 inches of either beach or dune sand had been deposited. The pipe was backfilled with this sand to at least the middle diameter. This was specified in order to provide a uniform foundation for the pipe. The steel pipe was joined in the field with an electric lap weld. After a section of the line approximately 800 feet in length had been laid and the field joints welded, the ends were bulkheaded and it was tested for leakage under a pressure of approximately 125 pounds per square inch. All the joints were examined while under pressure and where any leaks or sweats occurred they were repaired by either caulking or re-welding. After passing this test the joint was given a priming coat of "Oronite," followed by a heavy coat of the Petrolastic pipe dip. Reinforcing mesh was then carried around the joint, lapping that installed in the yard at least 4 inches and then the entire joint gunited. The bell holes at the joints were made large enough for the field welding and the field guniting. It was found necessary to have at least 30 inches in clearance all around the pipe at the bell holes. Manholes were provided for the painting of the inside of the pipe at the joints as well as for the installation of air and vacuum valves.

At the point where the line crosses Newport Bay as shown on the plan and profile, 24-inch flexible cast iron pipe was installed. The method of laying this pipe is shown in figures 16, 17 and 18.

CONSTRUCTION OF GRAVITY LINE

The gravity portion of the Laguna Beach pipe line consisted of centrifugally spun, reinforced concrete pipe varying from 27 to 18 inches internal diameter. This pipe was manufactured and in-

FIGS. 13 TO 15

FIG. 13. Field joint welded, painted and tested ready for gunite.

FIG. 14. Field joint being gunited after reinforcing fabric had been placed.

FIG. 15. A completed field joint.



stalled by the Western Concrete Pipe Company by the so-called "Hume" process. At the last annual convention of the California section of the American Water Works Association, Edward R. Bowen presented a very able paper dealing with the manufacture of that pipe,³ which was illustrated by moving pictures. The method of manufacture is essentially as follows:

Cylindrical steel forms are supported in a horizontal position on power driven rollers. These forms are split in the center for removal after the concrete is set. Inside this steel cylinder is placed the steel reinforcing which has previously been formed. The forms are then revolved and the concrete aggregate is shoveled into the cylinders. The concrete is uniformly spread over the inside of the form and the steel reinforcing centered by means of the centrifugal force of the revolving cylinder. The speed of the form is increased after all of the concrete has been deposited. As a result of this centrifugal force a very dense concrete is secured. All of the lighter or latent materials are forced towards the center of the form. After being spun in this manner for a length of time varying principally with the air temperature, they are brought to rest and all of the latent material removed by means of brushes. After these lighter materials, called "slurry," have been removed, the forms are again revolved at a relatively high rate of speed and the inside of the pipe burnished by passing a rod back and forth over the interior surface. This results in a very dense coating on the inside of the pipe of almost neat cement and gives the interior of the pipe a very smooth finish resulting in a high coefficient of friction. After the spinning process has been completed the forms are removed from the machine and are steam cured for at least 12 hours. Upon leaving the steam chamber the outside forms are removed and the pipe is further cured for 8 days under a sprinkling system in the yard.

Centrifugally spun concrete pipe is superior to the older method pipe made by pouring concrete materials between forms in many respects, the most important of which is the securing of a very dense concrete having a relatively high tensile strength. All of the stress in concrete pipe under internal pressure is tension. The general

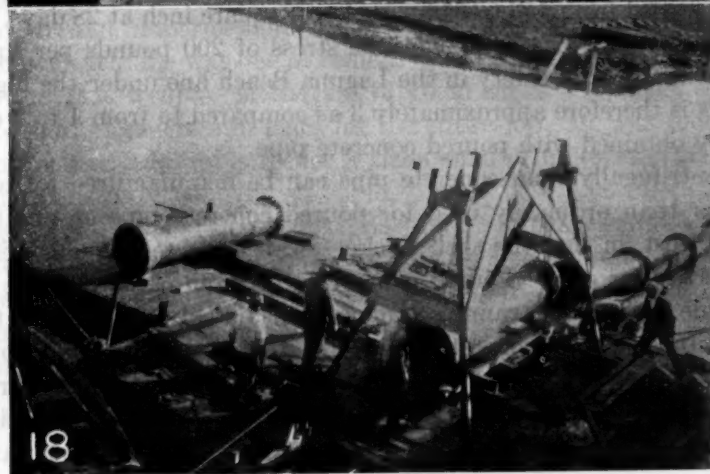
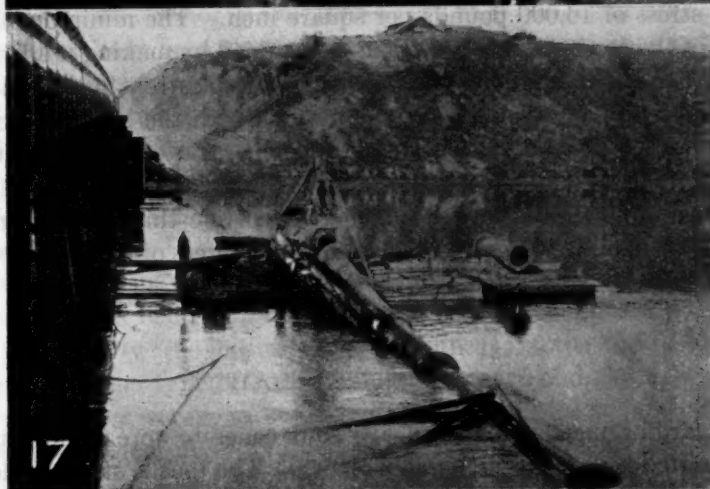
³ Journal, February, 1928, page 173.

FIGS. 16 TO 18

FIG. 16. Gunited steel pipe laid on peirs over bad ground.

FIG. 17. Laying flexible joint cast iron pipe across Newport Bay.

FIG. 18. Equipment used in laying submarine cast iron pipe.



theory of design is to provide sufficient steel reinforcing to carry the tensile stresses, surrounding the same with concrete for water tightness. Theoretically, however, the tensile stresses in the pipe are distributed between the steel and the concrete in the ratio of the modulus of elasticity of the two materials. It therefore follows that the steel and the concrete will act together to carry the tensile stresses until the concrete has failed in tension, at which point the concrete will crack and all of the load will be carried by the steel. This has been recognized in the past in the design of reinforced concrete pipe by providing sufficient steel to carry the load with relatively low unit stresses. In designing the pipe for the Laguna Beach line adequate steel was provided to carry the entire load with a unit stress of 16,000 pounds per square inch. The minimum thickness of the concrete shell was then determined by making it adequate to carry the maximum load with the unit tensile stress in the concrete not exceeding 200 pounds per square inch with the load distributed between the steel and the concrete in the ratio of the modulus of elasticity of the two materials, which was assumed to be 10 to 1. For the maximum heads in the Laguna Beach line this resulted in the following shell thickness for the various diameters of pipe:

<i>Diameter, inches</i>	<i>Thickness, inches</i>
27	2 $\frac{1}{2}$
24	2 $\frac{1}{2}$
18	1 $\frac{1}{2}$

Standard briquettes of centrifugally spun concrete were manufactured and tested by a local testing laboratory. The tensile strength developed varied from 450 to 650 pounds per square inch at 28 days. As the design was based on a tensile stress of 200 pounds per square inch the factor of safety in the Laguna Beach line under the highest heads is therefore approximately 3 as compared to from 1 to 2 ordinarily obtained with poured concrete pipe.

Centrifugally spun concrete pipe can be manufactured for heads higher than ordinarily used for poured concrete pipe at relatively lower cost, in that the shell thickness can be increased much easier and at lower cost. Poured concrete pipe requires both inside and outside forms which cannot be removed as quickly as the forms from centrifugally spun concrete pipe. In order to manufacture poured concrete pipe for high heads it will therefore be necessary for the contractor to have a large supply of forms resulting in a relatively high plant cost. Centrifugally spun concrete pipe, however, can be

manufactured for all reasonable thicknesses by varying the diameter of the end rings which can be removed shortly after the spinning is completed. The higher tensile stresses of centrifugally spun pipe also result in a thinner shell being required.

Another important point of superiority of centrifugally spun concrete pipe over the previous methods of manufacture is the method of joining the pipes in the field. With the type of joint used in the Laguna Beach line, which will be described later, it was found that the joint was stronger than the body of the pipe and that a certain amount of flexibility was provided which would permit of the expansion and contraction of the line without leakage.

Centrifugally spun concrete pipe, owing to its very uniform diameter and smooth interior surface, has a very high coefficient of friction. Tests which have been made on centrifugally spun pipe lines installed to date show coefficients of friction surprisingly high. Mr. Fred C. Scobey of the Department of Agriculture, who is probably the leading authority on the flow of water in concrete pipes, is to present a paper to this convention, and it is hoped that he will include results of his studies on this type of pipe.⁴

As the Laguna Beach pipe line was the first line of any size to be manufactured in California, it was necessary to do considerable experimenting before the best results could be obtained. This was particularly true in designing the proper mix, the time and rate of spinning, the type of steel reinforcing to use and the field joint. Specimen pipes were spun, having many variations in the mix. These pipes were tested under hydrostatic pressure. The results obtained were used in the selection of the proper mix to secure the maximum strength and impermeability. The mix finally adopted for the Laguna Beach line was one of cement to 2.3 of sand to one part pea gravel. This resulted in the use of 10.35 sacks of cement to one cubic yard of concrete in place for the entire job. It was found to be particularly desirable to use a clean sand of uniform grading.

The density of centrifugally spun pipe is best illustrated by its weight and the quantity of materials required for a given volume. Concrete manufactured by this process weighs approximately 155 pounds to the cubic foot, as compared to 145 to 150 for good poured concrete. Approximately 10 per cent more materials are required to manufacture a given volume of centrifugally spun concrete.

⁴ Journal, January, 1929, page 1.

In the first pipes made for the Laguna Beach line, the reinforcing was of the ordinary type of cage previously used in the manufacture of poured pipe. This consisted of a spiral of Bessemer steel wire held in position by spacer bars which were a flat rectangular shaped rod approximately $\frac{1}{2}$ -inch wide which was attached to the spiral by punching and crimping the edges. Under the centrifugal force of spinning it was found that this relatively broad bar was thrown close to the outside form because of its weight. In a number of pipes when the forms were stripped the spacer bar was exposed at the surface. When subjected to hydrostatic test and loaded to destruction, in nearly every instance the pipe failed longitudinally along these bars. To overcome this difficulty a special machine was devised for winding a cage of No. 8 or No. 10 high carbon steel wire. This wire was wound spirally back and forth until a cage was formed having the required cross sectional area of steel and which was particularly rigid. Figures 19 and 20 show clearly the type of reinforcing finally adopted.

After being cured in the yard one out of every 25 sections of pipe was subjected to hydrostatic test pressure equal to 150 per cent of the working pressure. Practically every section of pipe tested showed no cracking or seepage under this pressure. A number of the pipes were tested to destruction. Several sections of 27-inch pipe reinforced for 125 feet head, 14 to 16 days old, withstood an internal pressure of 107 pounds per square inch. Sections of the pipe were also tested from time to time to determine their strength under external load. The specified external loads which this pipe should stand were as follows:

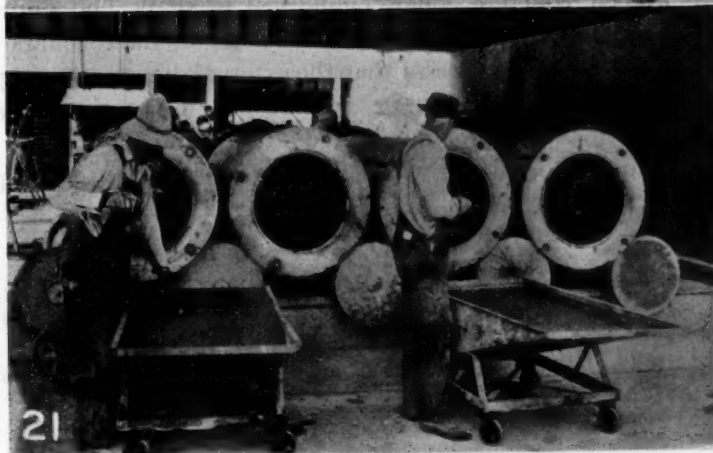
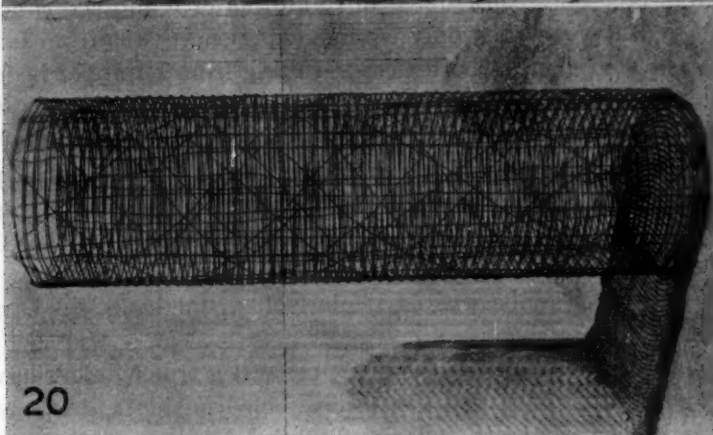
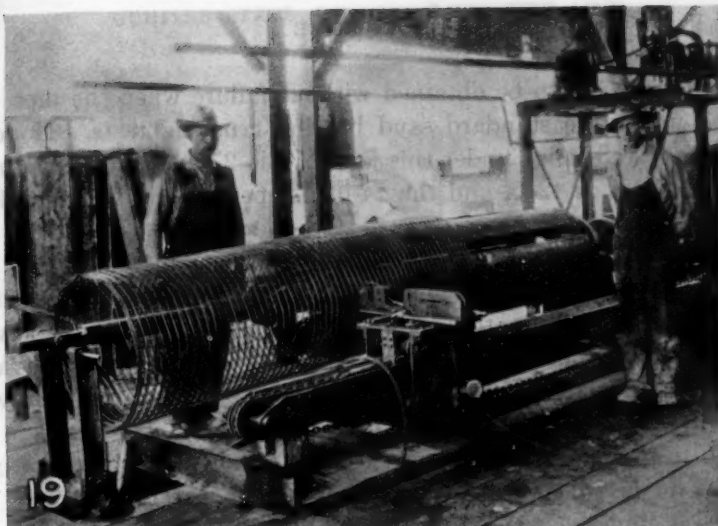
<i>Diameter, inches</i>	<i>Load, pounds per lineal foot</i>
27	3,300
24	3,000
18	2,200

FIGS 19 TO 21

FIG. 19. Machine for making reinforcing cage for centrifugally spun concrete pipe.

FIG. 20. Completed reinforcing cage made of No. 8 or No. 10 high carbon steel wire.

FIG. 21. Revolving forms used in manufacture of "Hume" spun concrete pipe. Concrete materials being shoveled in forms after reinforcing cage has been inserted.



These loads were to be obtained without failure when the pipe was loaded under the standard sand bearing crushing tests. None of the pipe tested failed under this load. The 27-inch pipe failed at a load in excess of 4200, and the 24-inch pipe at approximately 4500 pounds per lineal foot.

The pipe for the Laguna Beach job was manufactured in the contractor's yard in Los Angeles and hauled to trench side by trucks a distance of approximately 55 miles. It was laid in a trench having an average cover of approximately 3 feet. The trench was excavated to at least 4 inches below the subgrade of the pipe and backfilled with sand up to at least the middle diameter. The sand was placed in the trench to provide for a uniform bedding of the pipe which has been found to be particularly important under external loads. On two large pipe lines constructed in California of reinforced concrete pipe in recent years, the only trouble experienced was from failure due to external load, in both cases resulting from improper bedding of the pipe. The sand around the pipe had a further advantage in the heavy adobe soils such as obtained over a large portion of the line, in that it prevented the "heaving" and cracking of the pipe from expansion and contraction of the adobe soils when changing from wet to dry. In a number of cases where concrete pipe has been installed in these soils trouble has resulted from this condition. At places where the adobe was particularly bad, the sand was carried to the top of the pipe.

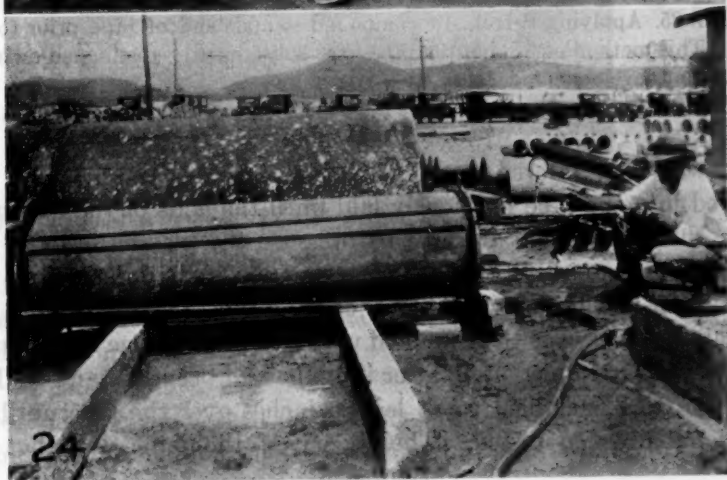
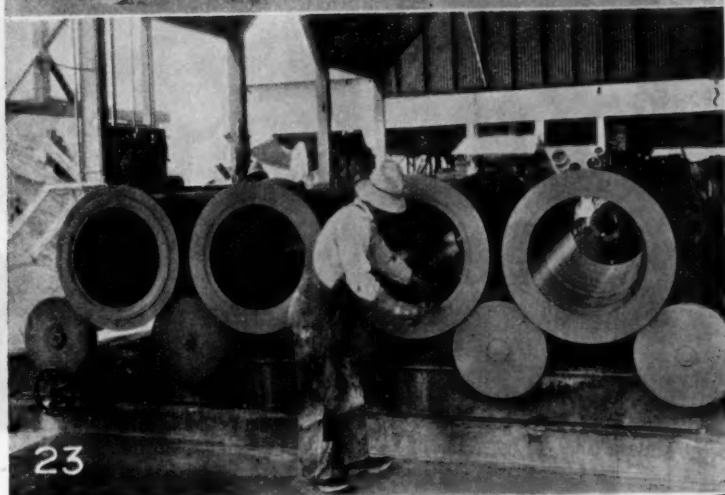
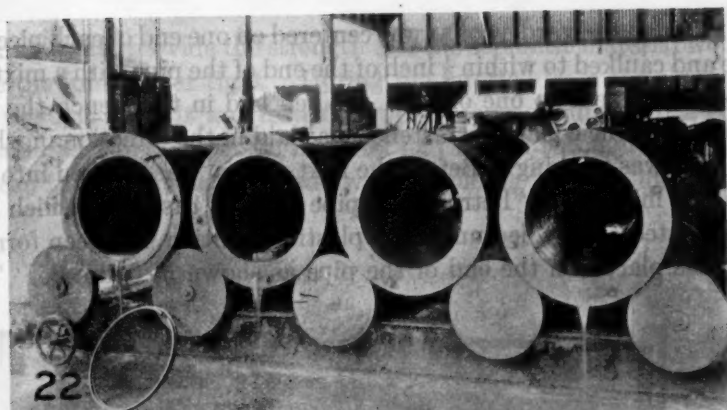
The pipe as it came from the machines was a true cylinder having the ends slightly concave. They were joined in the field by means of a reinforced concrete collar, cylindrical in shape and approximately 8 inches long. The internal diameter of these collars was approximately $1\frac{1}{2}$ inches greater than the external diameter of the pipe to be joined. They were spun in the machines in exactly the same manner that the pipe was manufactured. The inside of the collar was roughened to provide a bond with the joint material. After the pipe

FIGS. 22 TO 24

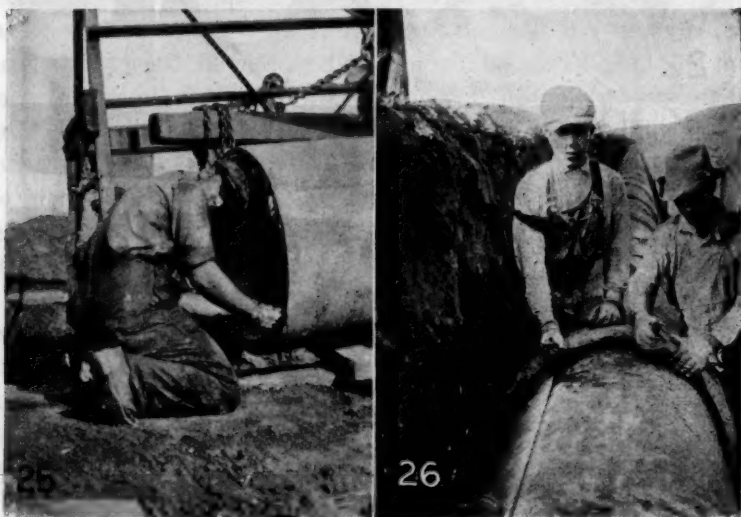
FIG. 22. At end of first spin at relatively low speed. Note excess water and lighter materials forced from concrete by centrifugal force draining from moulds.

FIG. 23. Final spinning at higher speed. Workman is burnishing interior of pipe with steel rod. This results in a high carrying capacity.

FIG. 24. Testing completed pipe under internal pressure.



had cured in the yard a collar was centered on one end of each piece of pipe and caulked to within $\frac{1}{2}$ inch of the end of the pipe with a mixture of one of cement to one of sand. When laid in the trench the end upon which the collar was fastened was laid in the direction in which the crew was working. Before the next section was lowered into the trench a mixture of "Petrolastic" pipe dip and castor oil which had been heated and cooled until in a plastic condition had been formed and was placed on the end of the pipe as shown in figure 25. The



FIGS. 25 AND 26

FIG. 25. Applying Petrolastic compound to male end of pipe prior to laying. This method of joining the pipes was subsequently abandoned owing to leaks that developed under test.

FIG. 26. Caulking annular space between pipe and collar at field joint.

pipe was then lowered in the trench and inserted in the collar and jacked into the pipe previously laid until the ends of the two pipes were flush together. Under this pressure the plastic material was supposed to completely fill the concave ends of the pipe as well as a portion of the annular space between the pipe and the collar. The remaining space was then caulked with a mixture of one of cement to one of sand. Immediately after the pipe had been laid and caulked the line was backfilled to at least 6 inches over the pipe until the section had been tested. The theory of the joint was that the

caulking would provide the strength and the asphaltic material would make the joint water tight. During the interval from the time the pipe was laid until it was tested, however, it was found that a considerable part of this plastic material had flowed through the crack between the ends of the pipe and was protruding into the interior of



FIG. 27. A typical syphon of spun concrete pipe on the Laguna Beach line.

the same. Upon subjecting the line to the test pressure it was found that a high percentage of the joints leaked. After trying many methods for repairing the joint it was finally found necessary to remove the caulking and the asphaltic material in the joints that leaked and recaulk the same with neat cement almost identical with the methods used in making the cement joint in cast iron pipe. A ring

of dry jute was caulked into the center of the collar approximately over the joint in the pipes. The other end of the collar was then caulked full of neat cement slightly moistened. After the joints had been repaired in this manner the line was again put under pressure and was found to be almost water tight, the leakage being but 10 per cent of the specified allowance of 200 gallons per inch of diameter per mile per day.

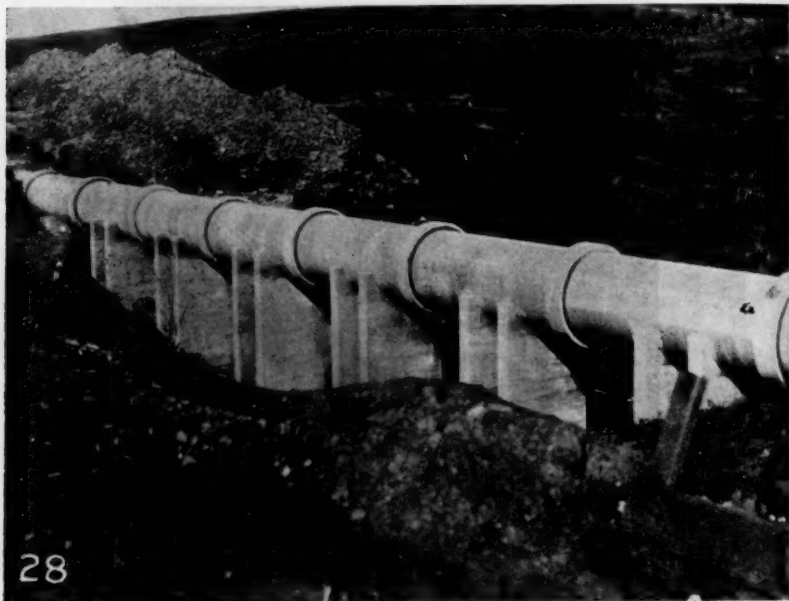


FIG. 28. Spun concrete pipe on piers in Laguna Beach line exposed to severe variations in temperature and expansion and contraction. No leaks have occurred.

The line has now been in service for over one year during which period no leaks of any consequence have developed. A recent test of its water tightness disclosed practically no leakage. On lines subsequently laid by the Western Concrete Pipe Company other methods of making the joint have been devised and I am informed by the engineers in charge of the same that the leakage has been nil.

The trouble experienced with the joints at Laguna Beach, while annoying and disagreeable, was no more than could be expected in the development of any new product and the satisfactory results finally obtained are in a large part due to the hearty coöperation of

TABLE 1

*Laguna Beach pipe line—cost data*43,451 linear feet of 30 inch-1³/₈-inch Gunited steel pipe

ITEM	CON-TRACT PRICE	TOTAL COST	LINEAR FEET	COST PER FOOT	
				For quantity done	For entire job
Trenching and Backfill (H. W. Rohl, General Contractor):					
1. General expense.....		\$ 3,349.00	43,451		\$0.077
2. Machine trench.....		11,005.26	39,261		
3. Hand trench.....		1,976.25	1,879		
4. River trench.....		4,544.68	1,255		
Total trenching.....		\$17,526.19	43,451		0.242
5. Excavation and piers for pipe laid above ground.....		774.00	770	1.005	0.018
6. Sand for backfill.....		4,160.56	34,900		0.096
7. Bellholes.....		6,193.49	41,140	0.151	0.142
8. Backfill.....		5,454.01	41,140	0.132	0.126
Total trench and backfill....	\$1.695		43,451		\$0.701
Steel pipe including freight to yard and field welding and painting (Steel Pipe & Tank Co. Sub-contractors).....	\$3.075		43,451*		\$3.075*
Guniting steel pipe including trucking from yard to trench and lowering in trench (Cement Gun Construction Co. Sub-Contr.):					
Yard work:					
1. Plant.....		\$ 2,379.74	43,608		0.054
2. Moving pipe in yard.....		243.32	43,608		0.006
3. Bracing interior.....		291.96	43,608		0.007
4. Reinforcing—labor and material.....		8,351.55	43,608		0.191
5. Guniting—labor, material and equipment.....		19,573.31	43,608		0.450
6. Curing.....		923.92	43,608		0.020
Total yard work.....					0.728

* Subcontract price.

The general contract for the installation of this conduit was let on September 10, 1936, and the specified completion date was Feb-

TABLE 1—Continued

ITEM	CON-TRACT PRICE	TOTAL COST	LINEAR FEET	COST PER FOOT	
				For quantity done	For entire job
Field work:					
7. Loading.....		\$1,247.68	43,608		0.031
8. Hauling.....		3,578.96	43,608		0.088
9. Laying.....		3,348.07	43,608		0.083
10. Field joints.....		4,352.55	43,608		0.111
Total field work.....					0.313
Total guniting.....	\$1.500		43,608		1.041
Total exclusive structures and special fittings.....	\$6.27				\$4.817

Note: The above costs represent field costs only. They do not contain contractor's profit, costs of bonds or any expenses of contractor's home office. All costs of structures were paid separately and are not included in the above costs.

the Western Concrete Pipe Company and their efforts to fulfill all the specifications without regard to cost.

At a number of points on the line the concrete pipe is carried across small arroyos on piers as shown in figure 28. The pipe at this point is entirely exposed and subjected to a wide variation in temperature. At the particular point shown in figure 28 the line also stands empty for substantial periods of time. The temperature range at this point is probably in excess of 50 degrees. With a variation such as this, coupled with the expansion and contraction from the alternate wetting and drying of the concrete as the line is filled and emptied, the joints have been subjected to a particularly severe test. Despite this condition no leakage whatsoever has developed at these points during the past year.

The line throughout its length was fully protected against air and vacuum. Blow-offs were provided at the low points. At numerous places connections were made for taking out water for service to the areas along the line.

PROGRESS

The general contract for the installation of this conduit was let on September 10, 1926, and the specified completion date was Feb-

TABLE 2

Laguna Beach pipe line—cost data

10,573.4 linear feet—27-inch Hume Concrete Pipe

<i>Length, feet</i>	<i>Head, feet</i>
4,578.9	25
4,195.7	50
594.6	75
522.1	100
682.1	125

ITEM	CON-TRACT PRICE	TOTAL COST	LINEAR FEET	COST PER FOOT
Total costs, exclusive of cost of pipe in yard (Western Concrete Pipe Co., Sub-Contractors):				
1. Cartage		\$ 5,361.06	10,574	\$0.507
2. Unloading		342.94	10,574	0.032
3. Machine trench		2,992.00		
4. Hand trench		845.50		
Total trenching		\$3,837.50	10,574	0.363
5. Bellholes and trimming		3,603.90	10,574	0.341
6. Sand for trench		2,556.33	10,574	0.242
7. Pipe laying		7,683.06	10,574	0.727
8. Caulking		1,496.69	10,574	0.141
9. Supervision		1,935.90	10,574	0.183
10. Backfilling, repairing defective joints, cleaning up and all expenses after all pipe laid—pro rated.....		7,281.75*	10,574	0.689
Total cost exclusive of pipe		\$34,099.13	10,574	\$3.225
Total average contract price including pipe:				
25 feet head	Cost	\$5.01		
50 feet head		4.65		
75 feet head		4.60		
100 feet head		5.80		
125 feet head		6.10		

Note: The above costs represent field costs only. They do not contain contractor's profit, cost of bonds or any expenses of contractor's home office. All costs of structures were paid separately and are not included in the above costs.

* Includes pro-rated costs after February 16.

TABLE 3
Laguna Beach pipe line—cost data
5520 linear feet—24-inch Hume concrete pipe

Length, feet		Head, feet	
325.1		25	
2580.8		50	
2050.0		75	
266.5		100	
297.6		125	

ITEM	CON-TRACT PRICE	TOTAL COST	LINEAR FEET	COST PER FOOT
Total costs, exclusive cost of pipe in yard (Western Concrete Pipe Co., Sub-contractors):				
1. Cartage and unloading		\$1,930.50	5,520	\$0.350
2. Machine trench		1,510.54		
3. Hand trench		1,506.10		
Total trenching		\$3,016.64	5,520	0.546
4. Bellholes and trimming		1,731.20	5,520	0.323
5. Sand for trench		1,536.40	5,520	0.278
6. Pipe laying		3,806.24	5,520	0.690
7. Caulking		781.58	5,520	0.141
8. Supervision		865.56	5,520	0.157
9. Backfill, repairing defective joints, cleaning up and all expenses after all pipe laid and caulked		3,231.60*	5,520	0.586
Total cost exclusive pipe		\$16,949.72	5,520	\$3.071
Total average contract price including pipe:				
	Cost			
25 feet head	\$3.85			
50 feet head	4.05			
75 feet head	4.35			
100 feet head	5.25			
125 feet head	6.00			

Note: The above costs represent field costs only. They do not contain contractor's profit, cost of bonds or any expenses of contractor's home office. All costs of structures were paid separately and are not included in above costs.

* Includes pro-rated costs after February 16, 1927.

ruary 21, 1927. All of the pipe was installed by February 1, 1927, but owing to the changes required in the joints of the concrete pipe the line was not put in service until the middle of March. When pipe was available at the yard an average of 550 lineal feet could be

TABLE 4

Laguna Beach pipe line—cost data

1570 lineal feet—18 inch Hume Concrete Pipe

length, feet

head, feet

1,213

25

357

50

ITEM	CON-TRACT PRICE	TOTAL COST	LINEAR FEET	COST PER FOOT
Total costs, excluding cost of pipe in yard (Western Concrete Pipe Co., Sub-contractors):				
1. Cartage and unloading		\$385.79	1,570	\$0.244
2. Machine trench		360.00		
3. Hand trench		101.50		
Total trenching		461.50	1,570	0.294
4. Bellholes and trimming		222.56	1,570	0.142
5. Sand for trench		414.00	1,570	0.263
6. Pipe laying		429.20	1,570	0.273
7. Caulking		100.75	1,570	0.064
8. Supervision		201.66	1,570	0.128
9. Backfill, repairing defective joints, cleaning up and all expenses after all pipe laid and caulked		657.51*	1,570	0.419
Total cost exclusive pipe		\$2,872.97	1,570	\$1.827
Total average contract price including pipe				
	Cost			
25 feet head	\$3.25			
50 feet head	3.40			

Note: The above costs represent field costs only. They do not contain contractor's profit, costs of bond or any expenses of contractor's home office. All costs of structures were paid separately and are not included in above costs.

* Includes pro-rated costs after February 16, 1926.

gunited per day by one gun. On straight going with no steep angles 1250 feet of steel pipe could be laid and the field joints welded per day. The best days laying was approximately 2000 feet. One crew could gunitite about 35 field joints per day. The rate of manufacturing the concrete pipe was limited by the forms available. The

laying of this pipe was necessarily slow at first owing to the experimenting necessary to develop the best type of equipment and methods. After the work was organized they were able to lay about 800 feet per day.

COSTS

The total cost of the Laguna Beach pipe line from the wells to its terminus, including all materials furnished by the owners, was approximately \$400,000. The unit prices bid for the various contract items were as follows:

1. Furnishing and installing gunited steel pipe	\$6.27 per foot
2. Installing 24-inch Cl. "B" cast iron pipe..	3.50 per foot
3. Installing 24-inch Cl. "B" flexible joint cast iron pipe.....	15.00 per foot
4. Furnishing and installing 27-inch concrete pipe:	
25 feet head..... { and	5.05 per foot 3.95 per foot
50 feet head..... { and	5.75 per foot 4.40 per foot
75 feet head.....	4.60 per foot
100 feet head.....	5.80 per foot
125 feet head.....	6.10 per foot
5. Furnishing and installing 24-inch concrete pipe:	
25 feet head.....	3.85 per foot
50 feet head.....	4.05 per foot
75 feet head.....	4.35 per foot
100 feet head.....	5.25 per foot
125 feet head.....	6.00 per foot
6. Installing 18-inch Cl. "B" cast iron pipe...	2.00 per foot
7. Constructing manholes and installing air valves.....	100.00 each
8. Constructing manholes and installing blowoffs.....	75.00 each
9. Plain concrete.....	20.00 per cubic yard
10. Reinforced concrete.....	35.00 per cubic yard

It is interesting to note that the total amount paid the contractor for extra work on the entire job was less than \$600. The conduit was installed under very rigid inspection and costs were kept of all features of the work. Tables 1, 2, 3 and 4 show the unit cost for the various sections together with the contract prices. They contain all field work, including labor and materials, furnished by the con-

tractor and cost of equipment used at a reasonable rental price. They do not include any expenses of the contractor's home office, costs of bonds furnished or profit. The unit costs while interesting can hardly be used in connection with new work owing to the time lost and expenses involved in developing equipment and methods for these hitherto unused pipes. This is particularly true with reference to the concrete pipe.

The conduit was designed and the construction supervised by Mr. Roy Browning, representing the Irvine Company, and Engineering Offices of J. B. Lippincott, representing the District. The writer was resident engineer in charge of the work in the field. Since the start of the Laguna Beach job steel pipe has been gunited for a number of other California water systems, the most important being the Sweetwater Water Company of San Diego, the East Bay Water Company of Oakland and the City of Riverside. Centrifugally spun concrete pipe has been installed for the cities of Riverside, Beverly Hills, Pomona and Sherman, California and at Phoenix, Arizona. A contract has recently been let for the installation of 15,000 feet of 51- and 63-inch spun concrete pipe by the City of Tacoma, Washington.

A NEW METHOD FOR DETERMINING SMALL AMOUNTS OF DISSOLVED OXYGEN¹

By F. R. McCrumb² and W. R. KENNY²

Dissolved oxygen is probably the outstanding influence in the corrosion of boilers and accessories. It must be reduced to a certain minimum, depending on conditions, in order to secure satisfactory service. Speller (1) states that the amount permissible depends upon the hydrogen ion concentration and the nature of the feed water, but, in some cases, e.g. large units operating at high pressure with evaporated water, the feed water should not contain over 0.05 cc. per liter of oxygen.

The method commonly employed for the determination of dissolved oxygen is the one proposed by Winkler (2) or some modification of it. This method depends on the fact that bivalent manganese is oxidized to a higher state of valence in an alkaline solution in the presence of oxygen. The resulting products are then allowed to act on potassium iodide in acid medium and the liberated iodine is titrated with a standard solution of sodium thiosulfate using starch as an indicator. Several modifications have been suggested from time to time in order to take care of interfering substances such as "organic matter," nitrites and iron (3, 4, 5). Aside from the interference of such substances, neither the Winkler method nor the modifications suggested, are particularly satisfactory for the low concentrations of dissolved oxygen ordinarily encountered in boiler water control. Small variations in titrations may cause marked differences in the results secured, due to the fact that the amount of standard thiosulfate solution required is quite small. Sodium thiosulfate solutions are not particularly stable and require frequent checking. If this is not done, the variations introduced when such a weak solution, 0.025 N or less, is used may be quite large. In addition some form of laboratory with the necessary equipment is

¹ Presented before the Water Purification Division, the San Francisco Convention, June 13, 1928.

² Research Chemists, LaMotte Chemical Products Company, Baltimore, Md.

required, which limits the use of the method in the field or industrial plant. Furthermore, the time required for a determination is somewhat long for control work.

A method which would overcome these difficulties would be desirable. Such a method should be accurate at low concentrations; it should enable one to carry out the tests rapidly with a minimum of manipulation preferably on the spot. Experience indicated that the simplest form of test for this purpose would probably be a colorimetric method.

Dissolved oxygen will readily oxidize ferrous iron and bivalent manganese in an alkaline solution, so some method based on such reactions was deemed most feasible. Forsberg (6), Hopkins (7) and one of us (8) have demonstrated that manganese in a state of valence over two will give a color with orthotolidin, which phenomenon will interfere in a determination of free chlorine by the orthotolidin method. It was, therefore, decided to determine if this reaction could be utilized in determining dissolved oxygen, making use of some form of comparator, similar to that described by one of us for the determination of low concentrations of free chlorine (8). Such a method appeared feasible for low concentrations, since oxygen, due to its low equivalent weight, should give even more pronounced colors with orthotolidin than does chlorine. In fact, preliminary tests made some time ago indicated that concentrations of oxygen of the magnitude of less than 0.05 cc. per liter would give an easily discernible color.

When the method was first tried the solutions used were those recommended in Standard Methods of Water Analysis, except, of course, that no potassium iodide was included. These solutions were: manganese sulfate, 480 grams per liter; potassium hydroxide, 700 grams per liter; sulfuric acid, concentrated; orthotolidin, 1 gram in a liter of 10 per cent (by volume) of hydrochloric acid.

Following the precautions which are given in Standard Methods for collecting samples, determinations were attempted in bottles which held exactly 65 cc. of sample. Manganous sulfate solution was introduced in 0.25 cc. portions, followed by 0.25 cc. portions of the potassium hydroxide solution. All precautions were taken to minimize introduction of air. The mixture was well shaken and the precipitate allowed to settle. When, however, the sulfuric acid was added, part of the precipitate went into solution very slowly and it required a large excess of acid to render this soluble. In the pro-

cedure given in Standard Methods the presence of hydriodic acid apparently facilitates solution, since no difficulty is encountered due to this factor.

While addition of the orthotolidin reagent apparently helped to dissolve this precipitate, it still required too much acid to effect solution, so this procedure was abandoned and the following solutions were tried: manganous chloride, 400 grams per liter; potassium hydroxide, 700 grams per liter and hydrochloric acid, concentrated.

In the next series of tests, the orthotolidin solution described above was used. A number of tests were carried out at one time, in which the oxygen content varied from sample to sample. Each sample was carefully analyzed by the method given in Standard Methods. No further difficulty was encountered, due to the slow solution of the precipitate when acidification was effected by the addition of 1 cc. of concentrated hydrochloric acid. However, it was noted that in samples of water which varied from 0.5 to 5.0 cc. of oxygen per liter, when analyzed by the Standard Method, there was very little variation in the color resulting when the orthotolidin reagent was added. The reaction between orthotolidin and the oxidized manganese appeared to strike an equilibrium which depended on the concentration of orthotolidin, for when the latter was increased, variable colors resulted. Satisfactory variations were secured with a reagent containing 10 grams of orthotolidin per liter. That such a solution can readily be prepared has been demonstrated (8). It is necessary, however, to reduce the concentration of hydrochloric acid to about 1.3 per cent by weight, or 30 cc. of concentrated acid per liter, to prevent precipitation of the dihydrochloride.

The preparation of color standards to represent such low concentrations of oxygen is a difficult matter and recourse was taken to a standard solution of potassium permanganate. A solution was prepared to contain about 1 gram per liter of potassium permanganate and carefully standardized against an accurately standardized solution of sodium thiosulfate, according to the method of Volhard (9). Using the standard permanganate solution, various dilutions were carefully prepared, which would be equivalent to 0.02, 0.04, 0.06, 0.08, 0.10, 0.15, 0.20, 0.25, 0.30 and 0.50 cc. of oxygen per liter at 0°C. and 760 mm. pressure. Immediately after each dilution had been made, a 65 cc. portion was treated with 1 cc. of concentrated hydrochloric acid and 1 cc. of the 1 per cent orthotolidin reagent. After five minutes the resulting color was simulated by means of a

dilute solution of a light fast dye, which gave corresponding colors. The preparation of each standard was completed within a very few minutes.

It is essential that water of high quality be used in carrying out the dilutions and it is recommended that such water be distilled first from alkaline permanganate and then from sulfuric acid. While the use of a light fast dye gave good results, the potassium dichromate and copper sulfate solutions ordinarily employed in the preparation of free chlorine standards can also be used.

Since a comparator method was desirable, the color standards were prepared in sealed nonsol glass ampoules, 22 mm. in diameter (20 mm. bore) and all comparisons were made by observing the solution through its horizontal thickness. A small comparator block was employed, which contained three slots and which had a piece of etched glass fastened on one side directly over the slots to eliminate reflections.

Determinations were now made on samples of water with a relatively low oxygen content. Several 5 gallon bottles were filled completely with distilled water. Portions of strong manganous chloride and potassium hydroxide solutions were introduced at the bottom, the bottles were then sealed tightly and the contents well mixed. These were allowed to stand over night and then analyzed for dissolved oxygen, both by the Standard Method and by the Colorimetric Method.

The Standard Method was followed in detail except that 0.01 N thiosulfate was used instead of 0.025, as recommended. This was done so that a larger titer could be secured.

In the colorimetric method the following solutions were employed: manganous chloride, 400 grams of $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$ per liter; potassium hydroxide, 700 grams per liter; hydrochloric acid, concentrated; orthotolidin solution, 10 grams of orthotolidin and 30 cc. of concentrated hydrochloric acid per liter.

The procedure employed was to collect the sample by siphoning into a glass stoppered bottle holding 65 cc. The siphon was discharged at the bottom of the sample bottle and at least ten times the volume of the bottle was permitted to overflow. Manganous chloride and potassium hydroxide solutions were then carefully added in 0.25 cc. portions. The bottle was quickly sealed without entrainment of air and the contents well mixed. The precipitate after settling was again mixed with the liquid and allowed to settle.

Hydrochloric acid and orthotolidin solutions were introduced at the bottom of the bottle in 1 cc. portions, the bottle was again sealed and the mixture well agitated. At the end of *five minutes* a portion of this mixture was transferred to a test tube having the same dimensions as the ampoules containing the color standards. The color of this portion was then compared with the color standards in the comparator and the oxygen content noted. Some of the results secured are given in table 1.

When it is realized that even with a solution of thiosulfate as dilute as 0.01 N, the variation per 0.1 cc. of solution will be 0.028 cc. per liter of oxygen, the above results are fairly consistent. When 0.025 N thiosulfate is used, a variation as low as 0.05 cc. of thiosulfate

TABLE 1
Determination of dissolved oxygen by different methods

OXYGEN BY DIFFERENT METHODS			
Standard Method	Colorimetric Method	Standard Method	Colorimetric Method
<i>cc. per liter</i>	<i>cc. per liter</i>	<i>cc. per liter</i>	<i>cc. per liter</i>
0.15	0.13	0.35	0.40
0.15	0.14	0.32	0.35
0.15	0.15	0.23	0.20
0.17	0.13	0.31	0.30
0.35	0.40	0.33	0.30
0.35	0.40	0.46	0.50

solution will cause a variation of 0.035 cc. per liter of oxygen which is appreciable.

While the colorimetric method is particularly adaptable to the determination of concentrations of dissolved oxygen under 0.5 cc. per liter it can be used for determining higher concentrations by employing the method of dilution. The determination is carried out in the regular way until the sample is ready to be compared with the color standards. If the value exceeds 0.5 cc. per liter, the test portion is diluted with a known amount of distilled water until the color falls within the range of the standards. If an equal volume of distilled water is required the value secured for the diluted portion is multiplied by two; if three times, it is multiplied by three and so on. Of course, the greater the dilution required, the lower is the accuracy, but fairly satisfactory results have been secured employing a dilution

as high as 1 to 20. However, a modification of this method is now being investigated in which color standards having a smaller diameter are being used. It is hoped that a satisfactory method for high oxygen content may result.

There are several factors which must be considered in using this colorimetric method, such as the effect of acidity, time, temperature and interfering substances.

The importance of acidity in the development of the orthotolidin color by oxidizing agents has been demonstrated (8). In order to secure a stable color the pH of the test portion should never exceed 2.0. In the case of boiler waters which happen to be fairly alkaline, it may be necessary to add additional hydrochloric acid to secure the proper conditions.

The maximum orthotolidin color develops within a few minutes, but it is recommended that a five minute period be used. A series of tests was made to determine the persistence of this color and it was found that no appreciable fading ever occurred within fifteen minutes. After thirty minutes fading was marked. Readings should be taken before ten minutes if possible, to avoid any possibility of fading. Elapsed time is reckoned from the time of addition of the orthotolidin reagent.

Temperature has some influence and all tests should be carried out between 20 and 30°C. (68 to 86°F.). This will necessitate cooling of boiler water and this can best be accomplished by drawing the samples through a cooling coil, preferably made from copper.

Both ferric iron and manganese in a state of valence over two will give a color with orthotolidin. In a determination of free chlorine the action of ferric iron is so slow that under ordinary circumstances there is no interference. In determining dissolved oxygen, however, the stronger orthotolidin reagent accelerates the formation of color to a certain extent and ferric iron over 10 p.p.m. may cause trouble. In the case of boiler water the soluble ferric iron and oxidized manganese compounds are hardly to be considered. The principal possible source of error would be due to the presence of scale or rust particles in the sample and their introduction should be prevented.

In case the colorimetric method is applied to materials other than boiler water, due consideration should be given to the comments of Theriault and Buswell, and reports on the work to which these comments refer (10).

The equipment for the colorimetric determination of dissolved

oxygen, as finally developed, consists of a set of color standards representing 0.00, 0.02, 0.04, 0.06, 0.08, 0.10, 0.15, 0.20, 0.30 and 0.50 cc. of oxygen per liter at 0°C. and 760 mm. pressure; 3 test tubes having the same bore and thickness as the standards; 50 cc. each of the manganous chloride, potassium hydroxide, hydrochloric acid and orthotolidin reagents of the concentrations last described; a glass stoppered bottle, having a capacity of 65 cc. when completely full, in which the tests are made; the necessary pipettes, two of 0.25 cc. and two of 1.0 cc. capacity, a dilution tube and a small comparator block, in which the comparisons are made. This equipment is compactly arranged in a portable wooden case, having the dimensions 13 by 5½ by 5½ inches.

The sample is drawn into the test bottle by introducing a tube which should extend to the bottom. At least five times the volume of the bottle should be permitted to overflow, preferably more, in order to completely displace all residual air which may have dissolved. Manganous chloride and potassium hydroxide solutions are now quickly introduced in 0.25 cc. portions, using the necessary pipettes. The stopper is inserted immediately without entrainment of air and the contents well mixed by inverting the bottle several times in succession. The resulting precipitate is allowed to settle partially, and the bottle again inverted. The precipitate is now permitted to settle and concentrated hydrochloric acid and orthotolidin solution are introduced at the bottom of the bottle in 1 cc. portions, using the necessary pipettes. The acid should be added first. The contents are well mixed and care should be taken that all the precipitate has dissolved. A portion is then transferred to one of the test tubes and the color compared with the standards in the comparator block. If the concentration exceeds 0.5 cc., a measured portion is diluted with distilled water in the dilution tube and the necessary correction made.

The advantages of the colorimetric method for dissolved oxygen are that it combines simplicity, convenience and rapidity with an accuracy sufficient for all practical purposes. The determinations can be carried out on the spot without the use of elaborate equipment, and all the necessary materials can conveniently be transported from place to place. The method gives consistent results for very low values of oxygen and fairly accurate results at higher values when the dilution modification is employed.

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The three systems used extensively to pump water from artesian wells are: the air lift; the reciprocating plunger pump; the vertical centrifugal pump.

The air lift system has until recent years been commonly used for pumping large and small capacities and from large and small wells. The units are usually driven by electric motors or steam engines of the flow-non-reversing or reversing type, and occasionally by oil or gasoline engines.

AIR LIFT TYPE

Advantages

It is able to discharge large quantities of water from high yielding wells of small diameter. For instance, with a 6-inch well a capacity of 800 or 1000 gallons per minute is beyond the capability of a plunger or vertical centrifugal pump; whereas, if the well has an exceptional yield and permits its pumping without an excessive draw down, an air lift may be used, provided the power cost permits its use.

2. A series of small wells may be pumped with one unit, thereby eliminating an individual unit for each well. For instance, if it is desired to pump six or eight 4- or 6-inch wells yielding 50 to 75 gallons per minute, it can be accomplished by means of an air lift with six lines connected to each small well and discharging into a common line. 3. An air lift is the only practical system for a cased well, as the pipes may be forced into the well and follow the bends without

DEEP WELL PUMPING¹

BY A. W. HEBBRING²

In choosing the proper type of pumps it is essential that due consideration be given to the size of the well, required capacity, depth of setting, depth of well, discharge pressure, source of power, and various other factors.

The three systems used extensively to pump water from artesian wells are: the air lift; the reciprocating plunger pump; the vertical centrifugal pump.

The air lift system has until recent years been commonly used for pumping large and small capacities and from large and small wells. The units are usually driven by electric motors or steam engines of the Uni-flow, non-releasing or releasing Corliss type, and occasionally by oil or gasoline engines.

AIR LIFT PUMPS

Advantages

1. It is able to discharge large quantities of water from high yielding wells of small diameter. For instance, with a 6-inch well a capacity of 800 or 1000 gallons per minute is beyond the capability of a plunger or vertical centrifugal pump; whereas, if the well has an exceptional yield and permits its pumping without an excessive draw down, an air lift may be used, provided the power cost permits its use.

2. A series of small wells may be pumped with one unit, thereby eliminating an individual unit for each well. For instance, if it is desired to pump six or eight 4- or 6-inch wells yielding 50 to 75 gallons per minute, it can be accomplished by means of an air lift with air lines connected to each small well and discharging into a common reservoir.

3. An air lift is the only practical system for a crooked well, as the pipes may be forced into the well and follow the bends without

¹ Presented before the Wisconsin Section meeting, October 12, 1928.

² Superintendent, Water Works, Wauwatosa, Wis.

affecting the operation of the system. This cannot be done where the crooks are excessive with a plunger or vertical centrifugal pump.

4. It is quite accessible.

Disadvantages

1. The predominating disadvantage of the air lift system is its low efficiency and resultant high power consumption. The power cost alone under average conditions is ordinarily 100 to 200 per cent higher than that of a plunger or vertical centrifugal pump.

2. Space required is comparatively large.
3. The system requires almost constant attention.
4. They are unsuitable for shallow wells.
5. They require a surface reservoir.

PLUNGER PUMPS

Advantages

1. They are efficient for small and large capacities.
2. Water can be discharged directly into the system against pressure.
3. They may be used in shallow wells.

Disadvantages

1. For large capacities and deep settings, the upkeep is comparatively great.
2. For large capacities, the cost is relatively high.
3. They are not suitable for crooked wells.

VERTICAL CENTRIFUGAL PUMPS

Advantages

1. They are efficient and the efficiency is maintained without constant overhauling.
2. They occupy a minimum of room and are exceedingly quiet in operation.
3. They require very little attention and are easily controlled automatically.
4. They can be used to pump directly into the system.

Disadvantages

1. For capacities of approximately 75 gallons per minute or less and small wells, 6-inch and less, the efficiency is low, and they are not as substantial as the larger sizes.

RECAPITULATION

The air compressor may be used where one desires to pump from a battery of small wells of small capacity, when it is necessary to do so, or when required to obtain a large amount of water from a small diameter well. They may also be used in a crooked well. In most cases it is a matter of economy for a user who requires a large amount of water to enlarge his well or drill a new one, rather than pay an excessively high power bill which may amount to the price of a new well in a short time. The writer has had occasion to view and discuss installations of air lift systems which have been replaced by vertical centrifugal pumps, and found that the power saving alone paid for the new pumping unit the first year.

The plunger pump is ideal for small capacities, provided the setting is not excessive. They are efficient as long as the condition is good, which means that they should be removed periodically and the leathers replaced.

As the efficiency depends on close clearances between the stationary and moving element, sand has a devastating effect on a plunger pump. Another trouble frequently encountered is that of breaking moving parts, particularly with deep settings when the thrust load is great due to the weight of the water, weight of the moving parts, plunger and rods, and usually a discharge pressure. The large capacity plunger pump may be subject to criticism when placed near homes, as they are usually rather noisy.

The vertical centrifugal pump, which has experienced a remarkable increase in popularity in recent years, is very efficient, particularly in the large sizes and capacities. The efficiency varies from about 60 to 75 per cent in capacities from 100 gallons per minute and up. The pumps built for heavy duty service are dependable, simple to operate, quiet, and easy to control.

SUPPLY OF WAUWATOSA

The city of Wauwatosa, with a population of over 20,000 persons, obtains its water supply from deep wells, having at present four wells and another in the course of construction. Two small diameter wells

are connected to an air lift unit, which was installed by the power company some years ago and pumped under contract by them. The contract has expired and the air lift is retained to help carry the summer peak demands. Well No. 3, which is 1703 feet deep and 16 inches in diameter, is equipped with a vertical centrifugal pump, set 200 feet measured to the bottom of the suction, and has a 75 H. P. motor mounted on the pump head and connected to the pump by means of a flexible coupling. It is controlled automatically by means of a float switch mounted in the reservoir. The pump delivered on test 1116 gallons per minute, and has an efficiency of 70 per cent. The pump was manufactured by the Layne-Bowler Company, and the motor and control by the General Electric Company. Well No. 4, which is 1804 feet deep and 15 inches diameter, is likewise equipped with a vertical centrifugal pump, set 400 feet measured from the base plate to the bottom of the suction. This is the deepest vertical pump in the state. It has a 150 H. P. motor, mounted on the pump head. It delivers 930 gallons per minute, and likewise has an efficiency of 70 per cent. The unit is controlled automatically by means of an automatic pressure regulator. This pump was also manufactured by the Layne-Bowler Company, the motor by the Allis Chalmers Company, and the control by the Sundh Electric Company. These pumps are oiled once a day, which requires about five minutes' time, and otherwise have no attention. The pump on Well No. 4 operates practically twenty-four hours per day, and no repairs have been required for either pump since installed.

SARASOTA'S NEW AUTOMATIC PUMPING STATION¹

By J. R. BRUMBY²

Sarasota's new water works pumping station is unusual in design and operation. It is said to be the only station in the country operated on this principle. The entire operation is automatic from the time the water leaves three 650 feet deep wells until it is discharged at 150 feet head into the distribution system.

The three wells have a positive head of 30 feet above sea level, and as the ground elevation is approximately 20 feet above sea, we can use horizontal centrifugal pumps. Three 640 g.p.m. 40 foot head DeLaval pumps, connected to a 10 h.p. motor having special fittings on the wells, pump directly to the reservoirs. They are automatically controlled by float switches.

The discharge from the wells are through Badger spray heads which aerate the water, removing all sulphur gasses. As one well is sufficient for the city's supply at this time, the wells are rotated in operation weekly, but all are so arranged that should the supply be needed they will automatically operate.

The two reservoirs are each 58 feet square and 13 feet deep. The old reservoir is not covered and is held in reserve for fire purposes. The new reservoir is covered with concrete, the cover sloping to the center with an opening in it so as to allow the water from the spray to enter. This opening is protected with fine copper screen, and a thin concrete slab to prevent the light from entering it.

The reservoirs are connected through a 16-inch suction main to the suctions of the high lift pumps in the station, and are on a loop so that either can supply the plant singly or jointly. Outside post indicator valves control the supply.

The main pumping station is designed with the pump level 3 feet above the bottom of the reservoirs giving a 9-foot head on the pumps at all times.

The pump pit has a balcony 8 feet wide over the pumps for in-

¹ Presented before the Florida Section meeting, April 4, 1928.

² Commissioner of Public Works, Sarasota, Fla.

spection, and the switch board is located on the west end of the balcony. There are two separate and complete pumping plants on the pump floor. One common suction header connects on each end to one of the reservoirs, and two suction mains lead off of this header. For convenience sake we call one "the north side system," or domestic consumption side and the other "the south side system," or fire pumps.

There are two separate discharge mains to the city connected together outside the plant with five indicator post valves on them. Two mains leave the plant for the high value district of the city, 12-inch on Orange Avenue and 12-inch on Central Avenue. These two streets are $\frac{1}{4}$ mile apart. These mains tie together at "Five Points," the heart of the city.

The "North Side" discharge main has a blank tee in it for a future elevated tank. It is planned to control the supply from this tank by electric operated gate valves in cases of fire, but normally it will "float" on the system. If the city had the funds at this time to install this tank it would further increase the efficiency of the plant, but in no way interfere with the automatic operation. As the system and plant is now designed, a very small tank would serve all purposes. I do not favor, for a city of any considerable size, the storage of water in elevated tanks. Their first cost and future maintenance is very high in this country.

The entire construction is of concrete and brick, the pump room is 30 by 45 feet, with concrete roof on steel trusses, absolutely fireproof. The front of the building is two stories, and not entirely fireproof, but all outside walls are brick, and all openings to the pump room have double fire doors. The bottom, or ground floor, is some 5 feet above the pump room, and is used as an office.

Upstairs is the operators apartment which includes two bed rooms, bath and kitchenette with Pullman dining room.

The unique feature here is the fact that one man operates the plant night and day, and he has very little to do except keep things clean, and the plant lawn and flowers in shape.

PRINCIPLE OF AUTOMATIC OPERATION

What makes it possible to operate with one man? The control of the pumps are automatic and still there is no elevated tank or stand pipe. The system is closed.

We shall follow the operation from, say, midnight through the

morning peak load, and perhaps have a sudden draft on the system during the night.

Normally at midnight or a little later, the city is asleep, so a 225 g.p.m. pump takes the load of waste and leaks. This pump operates as a pilot pump or comes into operation when all other larger pumps are off.

In the 14-inch discharge main is a flat plate orifice furnished by the Cochrane Flow Meter Company. The flow of water through this plate causes a difference in pressure on two small lines to a specially constructed "U" tube. One line is connected "upstream" and one "downstream." As the flow increases the mercury rises in one side of the tube and falls in the other. As the mercury rises it comes in contact with steel rods that make the circuit to start a larger pump. When the consumption falls off the velocity of water through the flat plate is less and the mercury falls leaving the contact and stopping that particular pump.

About 2 a.m. the Seaboard Air Line Railroad wants to water a locomotive, or Johnnie Ringling waters an elephant. Perhaps it takes 400 g.p.m. When the 225 g.p.m. pump reaches its full capacity the mercury rises and touches a contact that starts a 500 g.p.m. pump. As soon as the demand ceases, the mercury falls and the 225 comes back on and runs until the city wants more water than this pump can supply. This principle is carried through the entire plant.

The North side has four pumps; one 225, two 500 and one 1500 g.p.m.

The operation on increasing consumption is as follows. When the first 500 g.p.m. pump comes on it automatically cuts off the 225 g.p.m. pump, through an interlocking device on the starting switch of the first 500 g.p.m. pump. When the consumption reaches 500 or a little over, the 225 pump comes on again by mercury contact even though the 500 interlocker is "open." This gives a supply of 725 g.p.m. When 725 is reached the second 500 pump comes on and the 225 pump goes off, supplying 1000 g.p.m. Now when the 1000 is passed, the 1500 g.p.m. pump comes on. I find that one 1500 pump is more efficient than two 500 and one 225 running together, so this step is 1500 using a high efficiency DeLaval pump connected to a "slip ring" motor.

During the course of a day, pumps come on and go off, but at all times the pump or pumps running are very close to full load and

full efficiency. The daily automatic recording consumption and pressure charts indicate the operation of the plant.

There was one great difficulty to solve. Four pumps on one discharge main on the north side are controlled through one flat plate orifice. On the south side of the plant is a 2100 g.p.m. pump controlled through another orifice plate on its discharge main. How am I to start it and how am I to keep it running?

There is an extra contact in the north side "U" tube that starts the south side pump, and a second contact on the same pump on a separate "U" tube and orifice on the south side. This contact is so close to the mercury that the first "surge" from the 2100 gallon pump makes contact and holds that pump on while the north side mercury is falling. When the south 2100 gallon pump starts, its interlocking switch "clears" the entire plant and it runs alone.

The foregoing description of the operation of the plant might lead some to believe that the mercury contacts are on the control circuit of 220 volts of the automatic G. E. starting switches. They are not. Eighteen volts through a small solenoid magnet closes the 220 volt circuit and only 18 volts are on the contacts in the mercury and they are submerged in transformer on switch oil. This prevents all arcing at the points and they are less difficult to insulate.

The entire secret of the success of the automatic operation is in the way the current of 18 volts passes through the mercury and ground. Two contacts in the mercury "U" tube on each switch are used. The circuit closes when both contacts touch the mercury but does not open when one contact, which is shorter than the other, leaves the mercury, but only when both are clear of it.

I tried in vain to use one contact through a ground, but in operation the "surge" in the main and the sudden, even though slight, rise and fall in the mercury, caused a pump to come "on" and go "off" in rapid succession and made the system impossible. This led to a study of how to prevent this starting and stopping when I want the pump to run. The mercury touching the first or long contact rod does not start the pump, but touching a contact about $\frac{1}{16}$ -inch shorter starts the pump and the mercury would have to fall or surge $\frac{1}{16}$ -inch to stop the pump. This it has never done. This one feature allows me to start a pump "late" say at 525 g.p.m. for 500 gallon pump and stop it at 495 g.p.m. In other words, I have an overlap of any amount I want, by setting the points from 25 g.p.m. flow apart to as wide a range as desired. I do not want a pump on the

mains unless it is absolutely necessary, and when it does come on there is no reason to stop it until the service of water is down to where a smaller pump will care for it.

A diaphragm pressure switch closes when all pumps stop and the pressure falls below 45 pounds, and this rings an alarm bell in the operator's apartment. It is connected to the Sterling Engine starting battery. A further safeguard is a magnetic switch that rings a bell in the operator's apartment when the electric current goes off.

At this time we have only one 2100 g.p.m. pump, but floor space and blank tees are available for two more 2100, and another 2100 g.p.m. Sterling units.

The automatic capacity is 2100 g.p.m., but every pump in the plant can be started by pushing a button, for each pump, on the switch board, thus giving a total capacity of 6925 g.p.m.

The south side, or fire supply, also has a 225 h.p. Sterling engine directly connected to a 2100 g.p.m. pump on one end and a 45 K.W. 2300 volt generator on the other. This unit alone is a water plant in itself. The generator will supply current to pump all wells and light the plant, and the 2100 pump will supply the city in case of a long outage of current.

The capacity of the present plant is 4825 g.p.m. electric operated, and 2100 g.p.m. Sterling engine unit giving a total of 6925 g.p.m. All electric wire, switches and connections from the Florida Power and Light Company, have a capacity for the completed future plant of 9025 g.p.m. electrically operated. The total, including two Sterling units planned for, is 13,225 g.p.m.

Sarasota's water plant carries no deficiency charge from the Underwriters for a "first class" city of our size and future growth can be amply cared for up to around 50,000 population.

The switch board has a Florida Power and Light Company panel and a Sterling generator panel so arranged that no "cross" in current can occur. All pump starting switches are G.E. automatic remote control with special interlocking switch put on here during erection. Every motor including the well pumps are manually controlled by switch on the face of the switch board, besides the automatic control through mercury contact. The entire pumping and electrical equipment was furnished by Burford-Hall and Smith Company of Atlanta, Ga. The special mercury "U" tubes were made by the Republic Flow Meter Company.

This is the plant's thirteenth month of operation and it has not failed once. Power is seldom off, and it is seldom that the operator has to start a pump non-automatically.

The Sterling unit is run once a week with full load for one hour.

DISCUSSION

MR. REYNOLDS: Those are induction motors, are they not?

MR. BRUMBY: Yes. The 225 is 220 volts. One is a 220 volts squirrel cage motor, the other is a 2300, 75 horse power motor connected with a 1500 gallon pump. It is a Fairbanks-Morse and is the only piece of the old plant that is in use.

MR. REYNOLDS: The automatic system I suppose could be adapted to synchronous motors, or would it be difficult?

MR. BRUMBY: I am not an electrical engineer. Synchronous motors start automatically. The starting switches on these General Electric motors are remote control switches, push-button station switches.

MR. REYNOLDS: With a double mercury control contact? Each contract is part of a separate circuit?

MR. BRUMBY: Each contact. Two contacts go to this solenoid magnet, and to the ground. It takes two to start the pump, and when one is clear of the mercury the pump does not stop; both have to touch, and both have to clear the mercury to open, and in that way we get no lag on the pump. The pumps are set at about 40 pounds lap. Frequently the plant will be standing at a point of starting a pump, the pressure will be down to 60 pounds. Yet that pump will not come on. The flow in the main will drop and thus carry that pump at a high point of efficiency and load. We have had the mercury pots in operation thirteen months and they have not been touched. It is rather pleasing to find how well the adjustments of those contacts on the mercury stand. The pumps start today just exactly at the point where they started when the plant was put in. You are supposed to clean the mercury once every two years.

MR. REYNOLDS: Those are steel points, you say?

MR. BRUMBY: At first we used nickel, but we had trouble with the oil leaking out around the vacuum.

MR. WILLIAMS (West Palm Beach): I should like to ask Mr. Brumby if they have any difficulty in power factors?

MR. BRUMBY: We do not buy current on a power factor basis from the Florida Power and Light Company. We were using a maximum demand on the old plant of 95 K.W. In the new plant we are using from 62 to 65 maximum demand.

MR. ROBERTS: May I answer the gentlemen's question concerning the power factor? The conditions of operation established at Mr. Brumby's water pumping station are such that no motor operates at less than 75 per cent of full load. Therefore, the power factor of the motors he selected will always exceed 85 per cent when kept in proper repair.

MR. BRUMBY: Burford, Hall and Smith of Atlanta, Georgia, assisted me in selecting these pumps. Not knowing just exactly what we were doing, I would not say that this plant is as efficient as it would be possible to make a plant designed along the same lines. I believe it is the first installation of its kind, and there is a great deal yet to learn.

In regard to efficiency, the pumps are supposed to deliver, and under test they do deliver, the water in such a way that one pump does not back up on the other two, three or four pumps connected on the line. When in operation each pump delivers full capacity.

MR. CHAMBERLIN: Do you have any trouble when one pump comes on and another one goes off with the check-valve on the smaller pump slapping shut?

MR. BRUMBY: We did have.

MR. CHAMBERLIN: How did you overcome that?

MR. BRUMBY: We have balanced checks. I think it is a Golden-Anderson cushion check and does not make a sound when it closes, but originally the checks were placed in the suction line of the pump, and when the check closed the resultant water-hammer finally split the casing of the pump. We changed these checks over to the discharge side of the pump and put in Golden-Anderson cushion checks, and we are not troubled with any water-hammer and the checks close silently.

The State of Washington to National Standard Thread was issued. This means that all town departments and all private firms which want of which the Bureau could obtain any information have been worked over. (This was taken to standardize even very small quantities of hose wherever it could be found in an effort to completely eliminate non-standard thread. In some parts of the State, especially near Spokane, there had been great confusion in hose threads. Towns as close together as 2 miles were found to have give mutual aid and in several towns a variety of threads were found in the equipment of the town itself. All of this difficulty has been straightened out so that in the case of large lines there can be more intimate cooperation from nearby towns and fewer delays in the operation of the individual departments.

Aside from the added protection afforded the municipalities and property owners, there will be much less confusion in purchasing new equipment which will be taken to manufacturers as well as purchasers. It will, we assume, give your readers some pleasure to realize that the standardization movement has included one more state in the 100 per cent group.

J. K. WOOLLEY

ELECTROLYTIC CORROSION PREVENTIVE MEASURES

In an article in the October number of THE JOURNAL, Vol. 20, No. 4, page 505, appears an article entitled "Electrolytic Corrosion Prevention by Cathodic Protection" by F. G. Philo.

Mr. Philo makes the two following statements: "Corrosion will occur at the metal with the lowest solution pressure," and "Some of the more common elements may be listed in the order of decreasing solution pressure as follows: Gold, Silver, Copper, Hydrogen, Iron (ferrous), Lead, Iron (ferrous), and Zinc."

These two statements are incorrect. The author probably meant

Stanley, Washington University and Rating Bureau, Seattle, Wash.

DISCUSSION

STANDARDIZED FIRE HOSE THREADS

By the end of July, 1928, the work of converting all of the fire hose threads on $2\frac{1}{2}$ -inch couplings, hydrant outlets, and other apparatus in the State of Washington to National Standard Thread was finished. This means that all town fire departments and all private fire equipment of which this Bureau could obtain any information have been worked over. Care was taken to standardize even very small quantities of hose wherever it could be found in an effort to completely eliminate non-standard thread. In some parts of the State, especially near Spokane, there had been great confusion in hose threads. Towns as close together as 8 miles were found unable to give mutual aid and in several towns a variety of threads were found in the equipment of the town itself. All of this difficulty has been straightened out so that in the case of large fires there can be more intimate coöperation from nearby towns and fewer delays in the operation of the individual departments.

Aside from the added protection afforded the municipalities and property owners, there will be much less confusion in purchasing new equipment which will be a boon to manufacturers as well as purchasers.

It will, we assume, give your readers some pleasure to realize that the standardization movement has included one more state in the 100 per cent group.

J. K. WOOLLEY.¹

ELECTROLYTIC CORROSION PREVENTIVE MEASURES

In an article in the October number of THE JOURNAL, Vol. 20, No. 4, page 505, appears an article entitled *Electrolytic Corrosion Prevention of Condenser Tube Corrosives* by F. G. Philo.

Mr. Philo makes the two following statements: "Corrosion will occur at the metal with the lowest solution pressure" and "Some of the more common elements may be listed in the order of decreasing solution pressure as follows: Gold, Silver, Copper, Hydrogen, Iron (ferric), Tin, Lead, Iron (ferrous) and Zinc."

These two statements are incorrect. The author probably meant

¹ Manager, Washington Surveying and Rating Bureau, Seattle, Wash.

to say that corrosion will occur at the metal with the *highest* solution pressure and that the elements as listed above are in order of *increasing* solution pressure.

If, in a series of salt solutions having the same ionic osmotic pressure, bars of the corresponding metal are placed, the potentials developed in these solutions differ widely. This is due to the difference in solution pressures of the metals. Metals like zinc and magnesium will show a high potential developed in such a direction that a current flows from the metal to the solution if the proper conditions are presented. The solution pressure of each metal greatly exceeds the osmotic pressure of its normal ion.

On the other hand metals like silver and gold in contact with their normal ion also develop a potential, but of the opposite kind. This potential causes a current to flow from the solution to the metal. In such cases the osmotic pressure greatly exceeds the solution pressure.

W. A. KRAMER.²

In reply to Mr. W. A. Kramer's comment on my paper, I wish to state as follows:

The metals have been listed in the order as they appear in the potential series. The noble metals are assigned positive values in these series, and the reactive metals receive negative values. In the table given by Mr. Ulich R. Evans in his book above referred to, gold has an electrode potential of plus 0.99 volts, silver plus 0.7987, copper plus 0.3469, hydrogen 0.00, tin minus 0.146, and zinc minus 0.77. Concerning these values, Mr. Evans states:

"The convention adopted regarding signs of the electrode potential should be carefully noted. The 'noble' metals (such as gold, platinum and silver) are assigned positive values, while the 'reactive' metals (such as zinc, magnesium and potassium) receive negative values. This convention is now usually adopted in Great Britain, the United States and Germany, but in older papers the reverse use of signs will often be found, the potential of zinc being given a positive value."

Considering the reactive metals alone, it is true that the metal with the highest numerical values of solution pressure will be most corrodible, but as these values are negative, by definition, it was correctly stated in my paper, that corrosion will occur at the metal with the lowest solution pressure.

F. G. PHILO.³

² Chicago, Ill.

³ Superintendent, Steam Generation, Southern California Edison Company, Los Angeles, Calif.

TABLE 1

Behavior of various metals in presence of alkali

Certain preparations of iron and steel have shown resistance to the attacks of acids as shown by standard tests, but western waters are often alkaline, and resistance to alkali is a different problem. The United States Reclamation Service has made a series of experiments to test the virtues of various metals in the presence of alkali such as occurs in many western soils.

The results of these tests as reported by the project managers on three different projects are shown. All the sheets were planted in alkaline mud, the test samples being side by side, under conditions as similar as possible.

MATERIAL	METAL SHEETS IN ALKALINE SOILS				
	Weight	Length of test	Loss	Loss	Project
	ounces	years	ounces	per cent	
Toncan metal, galvanized.....	81.75	4	1.00	1.36	Sun River
Ingot iron, galvanized.....	88.0	4	1.00	1.14	Sun River
Mild steel, galvanized.....	79.50	4	1.00	1.26	Sun River
Toncan metal, ungalvanized....	73.75	4	5.50	7.46	Sun River
Ingot iron, ungalvanized.....	78.50	2	2.25	2.87	Sun River
Mild steel, ungalvanized.....	75.50	4	4.50	5.96	Sun River
Toncan metal, galvanized.....	81.00	2½	0.50	0.60	Uncompahgre
Ingot iron, galvanized.....	89.00	2½	1.00	1.10	Uncompahgre
Mild steel, galvanized.....	81.00	2½	1.00	1.20	Uncompahgre
Toncan metal, ungalvanized....	73.50	2½	4.50	6.10	Uncompahgre
Ingot iron, ungalvanized.....	81.50	2½	4.50	5.50	Uncompahgre
Mild steel, ungalvanized.....	76.00	2½	3.00	4.00	Uncompahgre
Toncan metal, galvanized.....	82.50	2½	2.50	3.03	Belle Fourche
Ingot iron, galvanized.....	91.00	2½	2.50	2.75	Belle Fourche
Mild steel, galvanized.....	81.00	2½	1.20	1.48	Belle Fourche
Toncan metal, ungalvanized....	78.50	2½	5.10	6.50	Belle Fourche
Ingot iron, ungalvanized.....	83.50	2½	4.70	5.63	Belle Fourche
Mild steel, ungalvanized.....	76.00	2½	2.20	2.90	Belle Fourche

The most striking result brought out by these tests is the immense advantage of galvanized sheets over those of plain metal. It is also made clear that none of the different special preparations tested have any great or uniform advantage over any others.

ARMCO INGOT IRON PIPE

On page 550 of Volume 20, No. 4, October, 1928, of *THE JOURNAL*, there is a discussion on *Armco* Ingot Iron pipe by Mr. J. P. Butterfield. This paper was presented for me by Mr. Butterfield because I was unable to attend the spring meeting of the New York section of the American Water Works Association.

It has been called to my attention that this information is being interpreted in some sections of the country, as a recommendation that plate metal pipe should be no lighter than $\frac{1}{4}$ -inch wall thickness.

Actually the type of pipe I had in mind when this article was written, was pipe in diameters of 30 up to 96 inches and used under high pressure. The siphons in the Los Angeles Aqueduct are specific examples of what I had in mind. Another example is the *Armco* Ingot Iron pipe now being installed in the Rio Claro project at Sao Paulo, Brazil, South America.

Pipe less than 30 inches in diameter of lighter wall thickness than $\frac{1}{4}$ -inch has been used in the past in many of our western states.

I suggest that the members of the water works profession be informed that the pipe under consideration in my original paper has nothing to do with the small diameter light weight pipe.

R. C. BEAM.⁴

Under the subject of "Discussion of Manual of Waterworks Practice," reprinted in October, 1928, issue of *THE JOURNAL*, Mr. J. P. Butterfield discusses the relative corrosion of ingot iron as compared to steel, and draws conclusions that are not justified by facts as found through the investigations of the United States Reclamation Service, the American Society for Testing Materials, and others.

The United States Reclamation Service has buried ingot iron, Toncan metal, and steel plates together in soils of several reclamation projects, and found that the ordinary steel would outlast either of the so-called pure irons. The results of these tests are found in the booklet entitled "Irrigation Engineering."⁵ Their results are shown in table 1.

Judging from these results, ingot iron is not as satisfactory as a good grade of steel, for water pipe.

J. J. WILSON.⁶

⁴ Development Engineer, The American Rolling Mill Company, Middletown, O.

⁵ Irrigation Engineering, by Arthur Powell Davis and Herbert M. Wilson, seventh edition, John Wiley & Sons, Inc., 1919.

⁶ National Tube Company, Denver, Colo.

ABSTRACTS OF WATER WORKS LITERATURE¹

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Flood and Frost Effects on Water Supplies. Anon. Surveyor, 73: 1887, 344, March 23, 1928. An abstract of a special report by Sir Alex. Houston describing special remedial measures taken during the frost and floods of January, 1928, to safeguard the water supply of London. The danger of severe frosts in causing large waste of water and excessive rates of filtration are pointed out; likewise their action in disturbing the proper action of slow sand filters and storage systems. Emergency chlorination is recommended for use on the occasion of floods or frosts.—A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).

River Pollution. F. H. HEALD. Surveyor, 72: 1869, 495, November 18, 1927. The author believes that much of the pollution of streams is due to psychological rather than financial reasons. While some municipalities are unable to finance sewage works, many now are delivering unsatisfactory effluents on account of improper operation of men inexperienced in the processes involved. Some industrial plants have disposal works delivering excellent effluents but also have an "unofficial" overflow into the stream through a storm water sewer or the like.—A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).

Typhoid Fever Epidemic, Santa Ana, California. CHAS. H. HALLIDAY and M. DORTHY BECK. Jour. Preventive Medicine, 2: 1, 49, January, 1928. The Santa Ana water supply was polluted through an old and forgotten sewer connection to the pump pit. The milk supply was contaminated also probably by a person infected from the water supply. In a population of 27,000 there were 10,000 cases of gastro enteritis and 620 cases of typhoid fever, of which 369 were water-borne, 200 from milk and 51 contacts.—A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).

Sanitation in Rural Areas. G. B. CHILVERS. Surveyor, 73: 1880, 185,

¹ Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

February 3, 1928. The problem of sanitation in rural areas is discussed from the standpoints of housing, water supply, drainage and sewerage, sewage disposal, refuse removal and disposal, and rural taxing. The rural housing problem is stated as being serious in Great Britain, owing to the insanitary condition of the older houses and the slowness of new construction, due to the high cost of building. The water supply problem also is difficult, few villages being able to have a pure and efficient supply. Dependence is mainly on scattered wells. Few villages are provided with proper means of sewage disposal.—A. W. Blohm (*Courtesy U. S. P. H. Eng. Abstracts*).

Uncle Sam Builds Pools for Boys in the Army. Anon. Jour. Amer. Asso. for Promoting Hygiene and Public Baths, 10: 37, 1928. A list is given of 59 army camps having Swimming Pools. Pool size and general nature are given.—A. W. Blohm (*Courtesy U. S. P. H. Eng. Abstracts*).

Pennsylvania Swimming Pools Further Interests by Organizing. CHARLES J. SCHMIDT. Jour. Amer. Asso. for Promoting Hygiene and Public Baths, 10: 39, 1928. A number of Pennsylvania Swimming Pool owners have formed an association to avoid unjust legislation and promote business. They propose a code and set of rules which if enforced would improve conditions very materially. They are cooperating with the State Board of Health.—A. W. Blohm (*Courtesy U. S. P. H. Eng. Abstracts*).

State Regulation of Public Baths, Swimming Pools, Laundries or Wash-houses, and Comfort or Convenience Stations. Anon. Jour. Amer. Asso. for Promoting Hygiene and Public Baths, 10: 59, 1928. A list of the states and possessions showing the existence of swimming pool regulations and date of adoption. Twenty-six states have regulatory laws.—A. W. Blohm (*Courtesy U. S. P. H. Eng. Abstracts*).

Colorado State Board of Health, Swimming Pools and other Bathing Places. Anon. Jour. Amer. Asso. for Promoting Hygiene and Public Baths, 10: 62, 1928. A copy of the Colorado Sanitary Engineering Law affecting swimming pools, either indoor or outdoor. Pools are divided into three classes. Class A pools offer "no reasonable danger of infection;" in class B pools the danger of infection is slight and class C pools are closed until they are made to meet the conditions demanded of A or B pools. Reproductions of forms, notices and reports are included.—A. W. Blohm (*Courtesy U. S. P. H. Eng. Abstracts*).

Biochemical Oxygen Demand. LEROY FORMAN. Public Health News, N. J. State Dept. of Health, 13: 6, 132, May, 1928. This article describes the results of several series of experiments in an attempt to secure uniform and consistent results in the determination of biochemical oxygen demand. Tests were made to determine the effect of using different temperatures for aeration of diluting water, the effect of aging diluting water, the temperature of incubation, the effect of using distilled or Trenton tap water and the effect of adding salts to increase the pH. Some of the conclusions are: (1) That all factors

must be controlled; (2) aged tap water is satisfactory at any one plant but for comparison of results with other plants a uniform diluting water is necessary; (3) the nature of the material is considered a less important factor than formerly; (4) "the greatest factor for obtaining good results in biochemical oxygen demand determinations are: (a) mineralized water preferably with potash salts with a pH well on the alkaline side; (b) well aged diluting water; and (c) incubation at a uniform temperature and not below 20°C." The paper is concluded with the modified procedure for biochemical oxygen demand determination adopted by the New Jersey State Department of Health.—*A. W. Blohm (Courtesy U. S. P. H. Eng. Abstracts).*

Treatment of Boiler Feed Water of Low Incrustant Content. S. C. JOHNSON. *Ind. Eng. Chem.*, 20: 1071-2, 1928. A description of the methods employed by the Chesapeake and Ohio Railroad at numerous watering points along that system using soda ash as the principal means of treatment.—*Edward S. Hopkins.*

Zeolite Softening of Lime Treated Water at Columbus, Ohio, Water Softening and Purification Works. C. P. HOOVER, V. L. HANSLEY and C. Q. SHEELY. *Ind. Eng. Chem.*, 20: 1102-5, 1928. The object of this investigation was to determine whether it would be more economical to soften, as at present, with lime and soda ash, or to use lime treatment with zeolite softening replacing the soda ash. The investigation was divided into three phases: use of green sand with upward flow; upward flow through Crystalite; and study of the characteristics obtained by mixing zeolite and lime softened waters. Complete description of the filter beds and details of operation are given. The investigation is not complete, but indicates that green sand has a softening capacity of 2500 grains of hardness per cubic foot and requires 0.35 pound of sodium chloride per 1000 grains of hardness removed for regeneration; that Crystalite has a softening capacity of 5000 grains per cubic foot and requires 0.35 pound of sodium chloride per 1000 grains of hardness for regeneration; that an upward flow filter has certain advantages. It is noted that the wash water used varied from 2.4 to 4.6 per cent. It is shown that by mixing in certain proportions the zeolite and lime softened waters a definite saving in operating costs should be expected.—*Edward S. Hopkins.*

Hydrogen Ion Control in Water Softening. JOHN R. BAYLIS. *Ind. Eng. Chem.*, 20: 1191-5, 1928. This paper shows that a knowledge of the pH of the water at various stages of the softening process will make possible more efficient operation of such a plant. Since the hardness of a saturated solution of calcium hydroxide is about 2200 p.p.m. and its pH value, 12.4, addition of free carbon dioxide will decrease this amount until a minimum of 13 p.p.m. is reached with a pH value of 9.4. Continued addition of carbon dioxide will further lower the pH, but increase the hardness by resolution of the carbonates, converting them into the bicarbonates. This condition indicates that at pH 9.4 the point of minimum solubility is reached for calcium carbonate. With magnesium hydroxide a saturated solution is obtained with 3 p.p.m. at a pH value of 10.6. Most magnesium is precipitated by converting it to

the hydroxide, whereas most calcium is precipitated by conversion to the carbonate. The problem therefore is to eliminate the magnesium in hydroxide form and the calcium subsequently as carbonate by reaction with carbon dioxide. These reactions can be more accurately and rapidly controlled by pH measurements than by the usual concentration procedures. A description is given of the methods employed in obtaining the pH values of saturated calcium and magnesium carbonate solutions, together with pertinent curves showing the effect of temperature upon these results. These curves have a very practical value in plant operation. Using Lake Michigan water it is noted that the pH "has great influence on the saturation equilibrium of calcium and magnesium carbonates." This water contains 34 p.p.m. Ca and 14 p.p.m. Mg. At a pH of 10.6 most of this Mg is precipitated leaving a residue of 3 p.p.m. Mg in solution. Subsequent carbonation will reduce the calcium content. If sufficient time (about twenty-four hours) is given equilibrium is established in accordance with the calcium carbonate curve. This is not practical in a softening plant, so it is suggested that the water be adjusted to the pH value giving maximum precipitation of calcium carbonate in three to four hours. Practical treatment of Lake Michigan water shows the value of this procedure.—*Edward S. Hopkins.*

Experimental Studies of Bacterial Death Rates in Polluted Waters. C. T. BUTTERFIELD. *Jour. Bact.*, 16: 257-67, 1928. The study shows the relationship between the well known phenomena of polluted streams decreasing in bacterial content and laboratory samples increasing, during approximately the same period of time. Using the Ohio River as a study, it was found that the polluted water leaving Cincinnati had certain characteristics and that considerable decrease in bacterial content was observed at Louisville, 130 miles down stream, after a period of flow of from eight to ten days. Using agar counts (twenty-four hours at 37°C.) it was observed that, with the river temperature varying from 10° to 27°C., an initial count of 99,000 at Cincinnati after two hundred hours of flow became reduced to 357 per cubic centimeter. Comparing this stream study with samples of the same water collected at the same time in glass bottles and held in the laboratory it was noted that with an initial count of 54,600, an increase to 216,000 bacteria per cubic centimeter was obtained in twenty-four hours and storage of 960 hours was necessary to lower this count to 2580, using 36 samples for the test. To more correctly simulate river conditions, 59 samples with an initial count of 240,600 were stored in 3-gallon pails. In 24 hours 447,700 were observed and in 144 hours 129,000; or no material decrease in the count by this length of storage. To give even more comparable results, artificial channels 0.8 mile long, were constructed and studies made upon the water flowing through them, the channels giving approximately a two-day flow. It was found under these conditions that the initial bacterial decrease is quite apparent and is followed by a secondary increase. The results are presented only as those under simulated natural river conditions. Excellent curves and tables are given.—*Edward S. Hopkins.*

Water Supply of Mason County Schools. CARL GROSS. *Illinois Health News*, 14: 5, 154, May, 1928. Inspections of 68 Mason County school wells

have just been completed, and among these only 2 cisterns and no dug wells were found; three of the wells inspected were within 15 feet of chemical toilet tanks. Twenty-seven wells were apparently of substantial and permanent construction, while the other 41 had wooden tops, or manhole covers, or cracked concrete tops. Analyses of samples of water from 50 Mason County school wells indicated only 2 bad and 8 doubtful samples.—*G. C. Houser.*

Running Water is Not Always Pure. Health Bulletin (North Carolina State Board of Health), 43: 6, 28, June, 1928. Reviews Public Health Bulletin No. 173, entitled "The Oxygen Demand of Polluted Waters." A water contaminated with the organic matters found in sewage and in various industrial wastes gradually rids itself of pollution, if allowed free access to air. In a given experiment with Ohio River Water collected at Cincinnati, oxygen continued to be used up for fully 300 days, and bacteria of intestinal varieties persisted for almost that length of time. For the average community, the amount of oxygen required each day for the stabilization of its carbonaceous waters will be about 100 grams per capita.—*G. C. Houser.*

Water Supplies Certified for Interstate Traffic. Health News (N. Y. State Dept. of Health), 5: 24, 94, June 11, 1928. Water provided for drinking or culinary purposes on any car, vessel, or other conveyance engaged in interstate traffic must be from a source certified and approved as producing water of satisfactory quality. During 1927, 128 supplies within New York State used for the purpose indicated were inspected and reported upon. Of these, 111 were certified by the Surgeon General to be of safe sanitary quality; temporary certificates for use pending the carrying out of recommendations were issued to 11; while the use of water from the remaining 6 supplies was prohibited.—*G. C. Houser.*

Liability for Water-Borne Typhoid. Health News (N. Y. State Dept. of Health), 5: 28, 111, July 9, 1928. Legal liability of private and municipal corporations for deaths and sickness caused by polluted water furnished by them is stated at length by J. A. TOBEY in Public Works for April. In order to recover damages, the plaintiff must prove (1) that the typhoid fever was actually contracted from the water furnished; (2) that the person or corporation supplying the water was guilty of negligence in allowing or failing to prevent the contamination; (3) that the injured party himself has exercised due care and was not guilty of contributory negligence.—*G. C. Houser.*

Pests. E. L. FILBY. Florida Health Notes, 20: 7, 103, July, 1928. In summer many pests in Florida warrant action by health officials. Among them are red worms in the water. Chironomus, the flying midge, lays eggs on the water and the red worms are one stage of the subsequent developments. As these worms seem to like water low in oxygen content, they are common in artesian well waters that are stored in open reservoirs. The only known remedy is covering the reservoirs.—*G. C. Houser.*

Typhoid Becoming a Rural Disease. R. H. RILEY. Press Bulletin 206: Maryland Dept. of Health, July 2, 1928. Twenty or twenty-five years ago, typhoid was as common in the cities as in the country. But with the installation of water and sewerage systems in cities and towns the danger to city people of contracting typhoid from drinking water has been greatly reduced. Now a very large proportion of cases in Maryland occur in scattered rural communities that are out of reach of adequately protected water supplies.—G. C. Houser.

The First Steps in Sanitation. Quarterly Bulletin, W. Va. State Dept. of Health, 15: 3, 4, July, 1928. Two commonly used methods of sterilizing water are (1) by boiling it for at least three minutes and (2) by use of chloride of lime. To sterilize an entire well, cistern, or spring, take one ounce of chloride of lime powder for each 1000 gallons of water. To insure safety, always have a slight taste of chlorine present in the water. Sketches and construction rules are given for protection of wells and springs from pollution.—G. C. Houser.

The Protection of Water Supplies. F. M. VEATCH. Bulletin of Arizona State Board of Health, July, 1928, p. 13. Recent investigation of an impounded supply at Wichita Falls, Texas, disclosed the fact that the normally soft and sweet water is being made hard and brackish by drainage from oil wells and by waste irrigation water which is very hard. Plan for protecting this supply includes a girdling ditch to carry the dry-weather drainage around the reservoir, the wet-weather flow being impounded. In Arizona, protection of water supplies is largely a matter of sterilization.—G. C. Houser.

Determining the Sanitary Quality of a Water Supply. JANE H. RIDER. Bulletin of Arizona State Board of Health, July, 1928, p. 17. Not more than 10 per cent of all standard (10 cc.) portions shall show the presence of organisms of the *B. coli* group, and in a series of less than 20 samples not more than one sample shall show the presence of *B. coli* in 3 or more 10 cc. portions. Quality of water cannot be determined definitely from laboratory analysis alone. Definite value may be assigned to the fecal and non-fecal members of coli-aërogenes group only when complete data concerning the supply are available.—G. C. Houser.

Financing Water Works Improvements. R. D. WHITEACRE. Bulletin of Arizona State Board of Health, July 1928, p. 19. All production and purification plant improvements and enlargements, belt line and feeder line installations, reservoirs and improvements of a general nature should be made from bond issues. Service mains should have the cost assessed to the property served, making the assessment large enough to cover the cost of a 6-inch main only. If necessary to lay larger mains on any particular street, the difference in cost should come from a bond issue.—G. C. Houser.

Pumping Equipment for Water Supplies. H. C. SCHWALEN. Bulletin of Arizona State Board of Health, July, 1928, p. 22. When its use is limited to

conditions for which it is adapted, the horizontal centrifugal pump with volute case, of single stage construction, is lowest priced and one of most efficient and satisfactory of all different types of pumps. It must be placed close to water table so that its suction lift will not exceed 20 feet. This type is not adapted for use where there is a fluctuating water table.—*G. C. Houser.*

Court Awards Damages for Death from Typhoid. Monthly Bulletin, Indiana State Board of Health, 31: 7, 109, July, 1928. Jury of Circuit Court of Adams County, Indiana, recently awarded damages in the sum of \$9,000 against City of Fort Wayne and Pennsylvania Railroad Company, because of a death from typhoid due to bad water in Ft. Wayne water supply, for which a cross connection with Pennsylvania Railroad industrial supply was responsible. This case, one of 23 due to an outbreak of typhoid in 1922, is now pending upon appeal before Supreme Court of Indiana.—*G. C. Houser.*

Ice. E. L. FILBY. Florida Health Notes, 20: 8, 115, August, 1928. Ice can roughly be divided into 3 classes in Florida; raw water ice, softened water ice, and distilled water ice. Most manufacturers soften their water before freezing, but do not exercise strict chemical control, and so often times ice with white cores is made. Air agitation is often employed to assist the freezing and reduce the cores. After the ice cake is partially frozen, the core of concentrated material is sucked out and refilled with new water. Soft water or distilled water, gives very little core.—*G. C. Houser.*

Pure Water. Health Bulletin (North Carolina State Board of Health), 43: 9, 30, September, 1928. (Quotation from Science News Letter.) Pure water was credited with reduction in use of alcoholic liquors and with bringing about prohibition in address by Dr. W. J. MAYO before American Chemical Society. Simultaneously with Vienna's introduction of a pure water supply from the mountains, her per capita consumption of spirituous and fermented liquors was reduced 40 per cent.—*G. C. Houser.*

Indoor Swimming Pools in Connecticut. W. J. SCOTT. Connecticut Health Bulletin, 42: 9, 187, September, 1928. The 1928 survey of indoor swimming pools in Connecticut suggests need for more supervision by local and state authorities. Samples for tests for bacteria, hydrogen-ion concentration, and alkalinity should be collected from the inlet and outlet ends of each pool at intervals of about two weeks and sent to approved laboratories for analysis. Daily tests for residual chlorine and for alkalinity, or hydrogen-ion concentration, should be made by pool supervisors.—*G. C. Houser.*

The Johnsonburg Outbreak. Pennsylvania's Health, 6: 5, 35, September-October, 1928. Owing to pollution of drinking water supply in an industrial plant in Johnsonburg, Pa., 28 cases of typhoid fever resulted, only employees of the plant falling victims. Investigation by state and local health authorities proved that town water supply was safe, but that after it had reached the plant in question, contamination occurred.—*G. C. Houser.*

Materials for Underground Pipe Lines. L. A. SMITH. *Virginia Municipal Review*, 5: 10, 177, October, 1928. Cast iron pipe is used almost exclusively for distribution mains in Wisconsin. Madison has used all types of bell and spigot pipe, and the author's opinion is that satisfactory pipe lines can be more economically laid using pipe prepared under other specifications than those of A. W. W. A. In Madison, pipe with an all-metal joint is used practically exclusively.—G. C. Houser.

Water and Sewage Analyses. E. S. CLARK. *Illinois Health News*, 14: 10, 331, October, 1928. State Department of Public Health has, since 1915, maintained water and sewage laboratories. There are now 505 public water supplies in the state, and routine periodic analyses are made of these supplies. Analyses are made of water from private wells and other private sources of water supply upon request. Other requests with which the water laboratory attempts to comply include determining medicinal value of mineral waters, presence of poison in water, suitability of water for fish hatcheries, muskrat raising, livestock, etc. Routine analyses of water samples from swimming pools are also made.—G. C. Houser.

False Results by the Ortho-Tolidin Test for Residual Chlorine. LEROY FORMAN. *Public Health News* (N. J. State Dept. of Health), 13: 11-12, 282, October-November, 1928. In an investigation of a surface water supply it was found that the results that one operator was obtaining for residual chlorine by means of ortho-tolidin tests several miles from point of application were actually higher than the total dosage being applied to the raw water. Manganese was found to be present. Experiments indicated that 0.1 p.p.m. of manganese in distilled water after conversion to form of hydrous oxide gave a color with ortho-tolidin corresponding to 0.13 p.p.m. of residual chlorine.—G. C. Houser.

Baffle-Pier Experiments on Models of Pit River Dams. I. C. STEELE and R. A. MONROE. Discussion. *Proc. Am. Soc. Civ. Eng.*, 43: 8, 2303-11, October, 1928. J. C. STEVENS. Experiments were conducted on one-twelfth size model of a diversion dam from the Leaburg hydro-electric development to be constructed on the McKenzie River by Eugene, Oregon. The development consists of a dam to raise the water 20 feet high and a canal of 2,200 second feet capacity 5 miles long. The model was made of lumber which had been soaked in water ten days prior to milling. Results of the tests are given. In all cases where the open baffles were used the hydraulic jump occurs well on the apron. With the solid baffle a double jump was produced, the second occurring below the apron and producing scour.—John R. Baylis.

Analysis of Arch Dams by the Trial Load Method. C. H. HOWELL and A. C. JAQUITH. Discussion. *Proc. Am. Soc. Civ. Eng.*, 54: 8, 2317-27, October, 1928. J. L. SAVAGE and I. E. HOUK. Several changes and improvements have been made in the methods for analyzing arch dams. In the original analysis of the Gibson Dam the sides of the cantilever were assumed to be parallel, the effect of shear in the arches was neglected, the foundation and

abutment rock was assumed to be rigid, and no arch action was assumed to take place until the increasing load had reduced the up-stream deflections of the cantilever to zero. In the revised calculations the sides of the cantilevers were taken as radial, the effect of shear on the arches was considered, the foundation and abutment deformations were taken into consideration, and the transmission of load to the abutments by arch action was assumed to begin as soon as the reservoir begins to fill. Temperature stresses in the revised calculations were based on actual measurements of concrete temperature variations. Diagrams showing the effect of considering shear, abutment deformation, and foundation deformation are given. Diagrams are also given of the load distribution and deflections in the original and the revised analysis. F. A. NOETZLI. The authors frankly assume that high tension stresses and numerous cracks are likely to occur in arched dams under load, and the final analysis of stresses is made by considering only the sections in compression.—*John R. Baylis.*

Upward Pressure Under Dams: Experiments by the United States Bureau of Reclamation. JULIAN HINDS. Discussion. Proc. Am. Soc. Civ. Eng., 54: 8, 2345-56, October, 1928. I. E. HOUK. At the American Falls Dam the pipes for measuring the upward pressure were placed before concreting, leaving the lower ends about 6 inches above the rock. After concreting the holes were drilled through the concrete and 5 feet into the rock. At the Gibson Dam the holes were drilled 18 inches into the rock. The depth to which the holes should be drilled into the rock, or whether they should be drilled at all, is a question that cannot be answered. The assumption that the pressure should be considered as acting over the entire base of the dam is favored, for there is no means of measuring accurately the area on which it is exerted. C. H. HOWELL. Water may develop pressure on the bottom area of a dam through faulty contact between the concrete and the top of the rock, or through open seams in the rock. Until the area affected by uplift can be determined the treatment of the problem will continue to be a matter of judgment rather than of mathematics. P. W. WERNER. Suggests building dams in blocks separated, except on the up-stream side, with fairly wide joints. The joints should be wide enough for forms to be removed. H. DE B. PARSONS. The uplift records of the Sherman Island Dam across the Hudson River showed an annual periodic variation which fluctuated with the temperature of the water. The uplift became greater as the temperature increased and less as the temperature decreased.—*John R. Baylis.*

Silting of the Lake at Austin, Texas. T. U. TAYLOR. Discussion. Proc. Am. Soc. Civ. Eng., 54: 8, 2350-91, October, 1928. P. A. WELTY. Most of the streams of the Southwest carry excessive quantities of silt. The writer discusses silt deposits in the canals of the San Benito Irrigation Project in Texas. Water is pumped from the Rio Grande River. Nearly 5,000,000 cubic yards of silt were deposited in the canals during the first ten years of operation. B. MCLAURIN. Lake Austin cannot be classified as a channel reservoir, for fully 50 per cent of the area was formerly beyond the channel. The width is being narrowed by silt deposits filling completely some of the

shallow areas. Lake Penick, which is the source of water supply for Stamford, Texas, had its capacity reduced from 3,094 acre-feet in 1920 to 2,129 acre-feet in 1927. R. G. TYLER. From the data at hand one might expect the Colorado River to carry about one per cent of its volume as silt. The silt content of various rivers is given. E. C. H. BANTEL. The silt accumulation in various reservoirs in Texas and New Mexico is given. The annual silt accumulation in acre-feet per square mile of drainage area varies greatly, and several reservoirs show an accumulation of over one acre-foot.—*John R. Baylis.*

Pumped-Storage Hydro-Electric Plants. WILLIAM W. K. FREEMAN. *Proc. Am. Soc. Civ. Eng.*, 54: 9, 2457-75, November, 1928. The Rocky River hydro-electric development near New Milford, Conn., is the first modern plant in America to pump water into a reservoir with off-peak power, in order to produce on-peak power later. Forty-two such plants have been built elsewhere, most of which are in Germany and Switzerland. Ten other plants have been proposed in Europe and 36 in America. The principle on which these plants operate is that of building a storage reservoir where the natural conditions are favorable for the economic storage and utilization of water and pumping with low-cost off-peak energy generated at steam plants or run-off-stream plants, in order to obtain high-value peak energy from the storage reservoir. Brief descriptions of the most interesting pumped-storage plants are included. There is also a discussion of their economic justification.—*John R. Baylis.*

Analysis of Arch Dams by the Trial Load Method. C. H. HOWELL and A. C. JAQUITH. Discussion. *Proc. Am. Soc. Civ. Eng.*, 54: 9, 2515-41, November, 1928. F. VOGT. A rough approximation based on correct assumptions with regard to shrinkage, temperature changes, yielding of foundation, etc., is more valuable than a highly refined computation based on wrong assumptions. The cylinder formula for arch dams probably can be made valid by using a multiple-pressure grouting system, dividing a number of the construction joints into closed compartments so that each of the compartments can be grouted under separate pressure. By such a system it would be possible to apply initial stresses in the dam, distributed in such a way that the resulting stresses due to load, shrinkage, cooling, and grouting are approximately equalized over the section. Dams constructed as at present without pressure grouting should be designed with constant radius where the canyon is wide as compared with the height of the dam. In the case of two recent dam failures, in which the arches did not fail, only factors other than those dealt with in the paper could have saved the arches. The stiffness against the tangential displacement may have been the most important factor. Tests to check the importance of this stiffness were made on a small rubber model in Trondjhem, Norway. Methods for computing the radial deflection in arches and tangential displacement are given in 44 equations. A. FLORIS. Methods for computing stresses in arched dams are discussed, and 25 equations are given.—*John R. Baylis.*

Precise Weir Measurements. E. W. SCHODER and K. B. TURNER. Discussion. C. HERSCHEL. *Proc. Am. Soc. Civ. Eng.*, 54: 9, 2501-4, November, 1928. The weir is not an accurate instrument for the measurement of water and the use of Venturi meters is suggested wherever it is possible for them to be installed. The discharge formula is expressed in the simplest of form. The meter need not be permanently installed and the cost of making flow measurements by the meter is usually less than by other methods.—*John R. Baylis.*

Silting of the Lake at Austin, Texas. T. U. TAYLOR. Discussion. *Proc. Am. Soc. Civ. Eng.*, 54: 9, 2545-58, November, 1928. R. F. WALTER. The original storage capacity (49,300 acre-feet) of Lake Austin was only about 1.4 per cent of the total annual flow, and it should be expected to fill with silt quite rapidly. The mean annual flow of the Pecos River at Lake McMillan is about 316,000 acre-feet. Forty-one thousand four hundred acre-feet of silt were deposited in the reservoir during the period from January 1, 1894, to June 1, 1915; whereas from June 1, 1915 to June 1, 1925, only 3,500 acre-feet were deposited. The reason for the marked reduction in the rate of silting is that since about 1918 dense growths of tamarisk have developed at the upper end of the reservoir. This has spread the water and caused the silt to deposit before it reached the reservoir. The Elephant Butte Reservoir is located in the Rio Grande Valley of New Mexico, and at the time of its completion had a capacity of 2,638,860 acre-feet, or 220 per cent of the mean annual run-off. The rate of silting is 20,508 acre-feet, or 1.64 per cent of the total reservoir inflow. Assuming the silting rate to keep up the total life of the reservoir would be 114 years. W. J. POWELL. Measurements of the silt deposited in White Rock Reservoir near Dallas, Texas, are given. Growths at the head of the lake have practically prevented silting in the main body of the lake. R. I. MEEKER. The Roosevelt Reservoir, which had an original capacity of 1,367,000 acre-feet, has a silt deposit of 101,000 acre-feet in twenty years. Over-grazing by sheep and cattle will deplete the grass carpet and contribute greatly to erosion.—*John R. Baylis.*

Early Intake Division Works Designed with Novel Features. CHARLES GEIGER. *Water Works Eng.*, 81: 21, 1479, October, 10, 1928. Water from the Moccasin Power Plant is diverted from channel of Tuolumne river at point called Early Intake, twelve miles below O'Shaughnessy dam and 156 miles east of San Francisco measured along aqueduct line. Diversion works consist of (1) a dam of pure arch type with thin section, crest elevation 2,356, length 262 feet, and radius of arch 100 feet; (2) spillway; and (3) headgates structure at tunnel intake. Total height of dam is 81 feet from its foundation which was excavated 26 feet below original river bed. Spillway is 13 feet wide, with capacity of 20,000 cubic feet per second. Lip of spillway is at elevation of 2,341, fifteen feet above tunnel invert, but by means of a series of five radial automatic siphon-operated gates, water surface above the dam can be raised five feet in periods of low water. Gates drop with rise of water to a predetermined point to pass the flood and rise again when flood has passed. A sand

trap 32 feet long and 5 feet by 5 in section provides for passing accumulations of sand through a 12-inch pipe through the dam, which is ordinarily kept closed, but can be opened in times of flood. Inclined screen racks prevent brush or other floating trash from entering tunnel. Nine sluice gates, 4 by 5 feet, arranged in two terraces, regulate flow of water into tunnel. Operating mechanism is enclosed in reinforced concrete housing surmounting the structure; a concrete wall above building gives protection against loose rock from mountain side. Illustrations given.—*Carl Speer, Jr.*

Data to be Considered in Designing Well Supplies. JULIAN MONTGOMERY. *Water Works Eng.*, 81: 21, 1480, October 10, 1928. According to published records, 70 per cent of the protected cities and towns in Texas obtain water from wells. These vary from 4 inches to 50 feet in diameter and from 15 to 2,000 feet in depth and are of three classes. (1) Large diameter wells. In these the greater diameter will permit the water-bearing sand to deliver more water to well and will give greater storage capacity. Where the economic rate of pumpage will yield a supply that is none too plentiful and where depth to water-bearing formation is not economically prohibitive, the large well with its ample storage capacity will permit of the maximum twenty-four-hour development of the well at minimum pumpage cost. In several cities wells are dug to a considerable depth below water-bearing sand, thus providing a correspondingly large reservoir in which the water can accumulate between pumpings. For 24-hour yield of water-bearing sand, only a few hours of pumping are required. (2) Shallow tubular wells. These for most part are driven or drilled wells, ranging in depth from 15 to 100 feet and of small diameter. Where a tubular well gives large yield, but has considerable draw-down, a turbine or air-lift pump is the most practical. In quicksands, yield may often be augmented and clogging troubles reduced by removing sand from around strainer and replacing it with well graded gravel. The effective diameter of the well then becomes that of the pocket of gravel. (3) Deep and artesian wells; found in practically every section of Texas. In some instances supply is so limited that pumping is resorted to. For very deep wells, air-lift pump is the practical installation.—*Carl Speer, Jr.*

Water Laboratories: Their Equipment. MELVILLE C. WHIPPLE. *Water Works Eng.*, 81: 21, 1469, October 10, 1928. Chemical and biological laboratory is important in organization of water works departments because it provides the only reliable service for operation and control of purification processes. Questions of policy should be given careful consideration to prevent subsequent confusion and misunderstanding. (1) Selection and layout of space. Easy accessibility to offices connected with laboratory and outside light are desirable; extremes of heat or cold (which will affect sensitive apparatus), dust, noise, and vibration are undesirable. (2) Equipment of apparatus and chemicals. Laboratory should be adequately equipped in the beginning and replacements and additions dealt with generously. Approximate estimates are given of sums required to fit various laboratories. Selection of equipment involves (a) visits to other laboratories and showrooms; (b) catalogues describing all forms of apparatus; (c) obtaining tenders from

reliable firms. (3) Details of equipment. Useful list of equipment given with approximate prices.—*Carl Speer, Jr.*

Developing Trees on the Watershed. F. A. LYON. *Water Works Eng.*, 81: 22, 1535, October 24, 1928. Considerable reforestation work has been done in watershed of Oneonta Water Department. Catchment area of Oneonta Creek is hilly country with steep gradients, with forested area small in extent, and with very few springs of magnitude; all of which features contribute to make the stream flashy in its flow characteristic and erosive. Water Board realized need to regulate stream flow in order to conserve supply and need to stop erosion. Farms were bought up and lands reforested. Planting was kept 100 feet from water to preserve clear shoreline. White pine, red pine seedlings, and European larch seedlings were set out about 6 feet apart. More than 500,000 cultivated trees are now on the watershed. Result has been found beneficial in reducing spring freshets, prolonging dry weather flows, and stopping erosive action of storm flows on steep hillsides. This care of watershed prolongs life of reservoirs, and secures more uniform volume of water. Bacterial quality of supply has also improved, but all water is filtered before reaching consumer.—*Carl Speer, Jr.*

Economy of Municipal Water Softening. W. J. HUGHES. *Water Works Eng.*, 81: 22, 1539, October 24, 1928. Advantages of softening of the water supply in bulk by the municipality are apparent. It is more economical and the softened water can be stored. Chemicals required and their costs depend upon kind and amount of hardness. Tabulations are given showing various processes and costs. Source of water supply determines type of treating plant required. In general well water contains as much temporary hardness as, and more permanent hardness than surface water. Surface sources come to be developed because of their greater reliability as to supply and their greater economic value when cost of pumping and treatment are taken into account. Five general classifications are given of selected types of plant based upon conditions of water and source of supply. The zeolite process is comparatively new for municipal work.—*Carl Speer, Jr.*

Fineness and Available Lime Content of Chemical Quicklimes. J. S. ROGERS. *Ind. Eng. Chem.*, 20: 1355-6, 1928. With hydration, quicklime is disintegrated into very fine particles, it being assumed that a properly burned lime will usually produce a hydrate passing a 200-mesh sieve. Such a state of fineness is very desirable due to increase of surface exposure thereby increasing solubility and speed of reaction. Sieving tests made with graduated sieves ranging from 30- to 200-mesh indicated that the majority of the limes tested did produce an excellent degree of fineness upon slacking. Tables are presented showing the relationship between particle size and availability.—*Edward S. Hopkins.*

A Comparison of the Acidity of Waters from Some Active and Abandoned Coal Mines. R. D. LEITCH and W. P. YANT. *Bureau of Mines Report*, Serial No. 2895: October, 1928. 8 pages. Previous investigations showed

that drainage from abandoned mines was usually lower in acidity than that from active ones in the same general area. This suggested the desirability of sealing abandoned mines to reduce the outflow of acid waters into receiving streams, and further studies were made to determine the worth of this thought. This report covers the work done in this connection. The writers review the methods of sample collection and testing and then discuss the results. The conclusions drawn include: (1) Acidity of waters from abandoned and sealed mines is lower than that from active mines which may otherwise be similar. (2) Water from abandoned mines is sometimes alkaline and usually has a low dissolved oxygen content; often zero, within the limits of accuracy of determination. (3) It is likely that sealing abandoned mines would hasten the decrease of discharge of acid water. (4) There is no direct relation between percentage of total iron in these waters and the proportion of ferrous and ferric salts in solution. (5) With lower percentages of dissolved oxygen in abandoned mines waters, ferrous sulphate is correspondingly high.—*Arthur P. Miller.*

The New Water Works in Greenwich, Conn. E. SHERMAN CHASE. *The American City*, 39: 6, December, 1928. The new rapid sand filtration plant of the Greenwich Water Company is described in detail. This plant is conventional in design, but has many unique and interesting features. The raw water is aerated by the use of 48 Sacramento type floating spray nozzles located on the roof of the covered coagulation basins. The aerated water drains through a conduit to two 18 feet square mixing tanks with an effective depth of 17.5 feet. Mixing is secured by mechanically driven wooden paddles which are designed to revolve at the rate of about one revolution per minute, although interchangeable gears provide other speeds. With the plant operating at the ultimate capacity of 8 m.g.d., these mixing tanks provide a period of fifteen minutes. Provision has been made for the installation of filtered water aerators over the covered pure water basin, if such is found to be desirable in the future. Attempts have been made to reduce the amount of supervision required in the operation of the plant through the use of automatic and remote control devices. The low-lift pumps are driven by variable-speed motors permitting close adjustment of the rate of pumping and may be controlled either from the chemical house or at the low-lift pumping station. The level of the water on the filters is controlled by a special differential mechanism operating a four-way valve which throttles the discharge of the low-lift pumps. Wash water pumps are used rather than elevated tanks. The rate of washing the filters is controlled by an automatic rapid controller on the discharge pipe of these pumps. Telephones have been provided to facilitate communication throughout the plant.—*C. R. Cox.*

Sanitation of Watersheds. E. SHERMAN CHASE. *American Journal of Public Health*, 18: 11, 1339-1346, November, 1928. This paper gives a detailed discussion of the many problems dealing with the sanitation of watersheds. Six states have specific regulations pertaining to watershed sanitation, and seventeen more have general regulations upon this subject. The remaining states have no regulations. The author is of the opinion that municipali-

ties and water companies should make every effort to purchase catchment areas or otherwise control sanitary conditions on watershed. Typhoid statistics are quoted as indicating that the rates are lowest in those states where for many years the general policy has been to rely upon the purification of water in large storage reservoirs, and also where catchment areas have been maintained free from sources of pollution through purchase of land. Such a policy would prevent the recreational use of watersheds, which is becoming more and more popular, and would be difficult to follow when large streams are sources of water supply. This situation presents a difficult problem to public health and water supply authorities.—*C. R. Coz.*

The Mount Airy Water Works. P. P. PHILLIP. *The American City*, 39: 6, 137-140, December, 1928. Brief description of the water works system of Mount Airy, North Carolina, and the new mechanical filtration plant of conventional design.—*C. R. Coz.*

Industrial Viewpoint of the Phenol Waste Disposal Problem. FRANK F. MARQUARD. *American Journal of Public Health*, 18: 12, 1497-1500, December, 1928. This article describes the experience at the coke plants of the Carnegie Steel Company since 1906 in the prevention of the pollution of natural waters with phenolic wastes. This company has installed recirculating quenching systems whereby the waste waters containing phenolic bodies are evaporated during the quenching of coke.—*C. R. Coz.*

The Application of Hydrogen Ion Control to Water and Sewerage Work. W. A. TAYLOR. *Southwest Water Works Journal*, 10: 9, 9-16, December, 1928, 5 fig. An explanation of the meaning of hydrogen ion values and of colorimetric method of measurement of pH with description of apparatus. A brief but very good outline is given of applications of hydrogen ion control to water purification, sewage treatment, industrial waste disposal, and control of corrosion by brines and boiler feed waters.—*John H. O'Neill*

Copper Service Pipe. M. B. CUNNINGHAM. *Southwest Water Works Journal*, 10: 9, 16-18, December, 1928. Copper pipe is 99.9 per cent pure copper, is a thin-walled copper tubing with flared end connections, comes in lengths up to 60 feet and in $\frac{1}{2}$ -inch to 2 $\frac{1}{2}$ -inch sizes, chiefly used between main and curb. It is the cheapest of non-corrosive materials, can be installed quickly and without the usual flange trouble, is flexible, and has a bursting pressure greater than any other commonly used pipe. It resists bursting when frozen, resists corrosion, and its flow capacity is almost constant throughout its entire use.—*John H. O'Neill.*

Vilket inflytande kunna i fiskfäces förekommande bakterier utöva på resultatet av Eljkmans jäsningsprov. (What is the Influence of Fish Feces Bacteria on Results of the Eljkmann Fermentation Test?). HARALD HUSS. The Stockholm Water Works Laboratory. Särtryck ur Hygiea Medicinsk Tidskrift utgiven av Svenska Läkaresällskapet. 1919. *German summary translation.* In addition to answering the question of degree to which fish feces bacteria

influence the results of the Eijkman fermentation test, the author shows that true *Bact. coli*, as found in warm blooded animals, is seldom found in the flora of the fish intestine. Of 37 fishes examined only five produced gas at 45°. *Bact. coli* was isolated from four of these. The author is of the opinion that the few *Bact. coli* colonies at 45° were probably present in the fish intestine by accident, having gained entrance with food. He also assumes that *Bact. coli* of warm blooded animals do not find, in the fish intestine, conditions suitable for multiplication. The *Bact. coli* growing at 45° seem, in all probability to occur only in fish that have lived for a longer or shorter period in waters highly polluted with feces of warm blooded animals.—R. E. Noble.

Om klorering av avloppsvatten. (Sewage Chlorination). HARALD HUSS. Göteborg, Centraltryckeriet. O. Ericson. Stockholm, June, 1925. German summary translation. Sewage was used from a part of Stockholm serving 70,000 population in experiments described. The study was chiefly concerned with domestic sewage. The gas titre of this sewage fell between 0.00001 and 0.000001 cc. The forty-eight-hour gelatin count at 20° to 22° fell between five and ten million per cubic centimeter. The 45° count on Congo-red-lactose-agar, growing acid forming bacteria, was 180,000 to 300,000 per cubic centimeter. The sewage was first filtered through cotton and freed of the coarser material. The experimental temperature was 18° to 20°. The action of the chlorine was determined by gelatin counts. Fifty grams of chlorine per cubic meter was necessary to kill all bacteria. The addition of 100 grams however, did not kill fungus forms. After one hour, at a dosage of 5 grams of chlorine per cubic meter, only 0.03 to 0.1 per cent of the forty-eight-hour gelatin bacteria remained. Of these bacteria, 0.001 per cent survived disinfection after the addition of 10 to 20 grams. Sooner or later, however, a rapid increase in the bacteria takes place. At the same time H_2S is given off gradually. H_2S was found in sewage as follows:

Without chlorine after 3 days

With 2.5 grams Cl per cubic meter after 5 days

With 5.0 grams Cl per cubic meter after 6 days

With 10.0 grams Cl per cubic meter after 6 days

With 20.0 grams Cl per cubic meter after 13 days

With 30.0 grams Cl per cubic meter after 17 days

With 40.0 grams Cl per cubic meter not after 40 days

Thus the use of chlorine seems indicated when it is desired to arrest for a time the processes of decomposition. These laboratory experiments must be supplemented by large-scale experiments in actual practice. Experiments under natural conditions may perhaps give better results than those in the laboratory where the supply of necessary air and light is restricted.—R. E. Noble.

Weshalb fällt die Eijkmansche Gäsprobe mit nitrathaltigem Wasser negativ aus? (Why does the Eijkman Fermentation Test Fail With Water Containing Nitrate?). HARALD HUSS. Biologisches Laboratorium des städtischen Ge-

sundheitsamtes zu Stockholm. Sonderabdruck aus Centralblatt für Bakteriologie, Parasitenkunde, und Infektionskrankheiten. February, 1926. According to the opinion of the author, the following seems to be the explanation: because the nitrate protects the dextrose from that form of attack by the *B. coli* which results in gas formation but not at all from that which results in acid formation. This protection apparently exists as long as a trace of NO_3^- or NO_2^- remains in the mixture. When the NO_3^- content of the water is so great that the acid formation from the dextrose, which proceeds side by side with the nitrate reduction, raises the hydrogen-ion concentration to such an extent as to render the medium no longer suitable for the continued development of *B. coli* before the nitrate has entirely disappeared, then the test becomes negative. When the nitrate content is less, say 100 mgm. per liter, a positive gas test is obtained. Upon the addition of 1 gram K_2HPO_4 to 100 cc. of sample, a positive gas test may be obtained where previously the results were negative, even though the water should contain up to 200 mgm. NO_3^- per liter. With the examination of each water sample a determination should be made for the presence of bacteria capable of splitting lactose at a temperature of 45° . This determination can be most conveniently accomplished by the use of congo-red-lactose-agar plates. Herein are mixed 10.0 cc. of congo-agar with 10.0 cc. of water. The plates are incubated twenty-four hours at 45° and the black colonies counted. By this method the worker obtains an exceedingly valuable control of the fermentation test. Furthermore it affords a more accurate determination of the bacteria fermenting lactose at 45° , usually *B. coli*. When the fermentation test and congo-agar plates are run in parallel, and only the latter indicate the presence of *B. coli*, the bacteriologist should regard it as a sign to test the water for nitrate. As pointed out, such disagreements may be prevented by adding K_2HPO_4 in the fermentation test at the start.—R. E. Noble.

ABSTRACTS SUBCOMMITTEE NO. 9

JOINT RESEARCH COMMITTEE ON BOILER FEEDWATER STUDIES

Modern Mineral-Water Plant. F. BORNHEIM. Eng. Progress (Berlin), 9: 10, October, 1928, pp. 285-287, 4 figs. Article which is intended to be first of series describes one of latest combinations consisting of impregnating plant and revolving counter-pressure filler.

The Use of Alloy Steels for Boilers. J. V. ROMER and W. W. EATON. Boiler Maker, 28: 9, September, 1928, pp. 261-262. Corrosion and heat-resisting materials necessary to meet high-temperature and pressure conditions: ultimate tensile strength, elastic limit, elongation, and impact resistance over entire range of temperature for which material is being considered; properties that must be investigated are thermal conductivity and coefficient of expansion; properties of chrome-nickel-iron alloys.

Notes Concerning Fractured Boiler Plates. G. NESS and D. A. MACCALLUM. West of Scotland Iron and Steel Inst., JI., (Glasgow), 35: 6, March, 1928, pp. 101-107 and (discussion) 107-109, 24 figs. on supp. plates. Suggests

that caustic embrittlement is not only cause of cracking of boiler plates; investigations by boiler inspecting companies produced evidences of fracture in several cases which are submitted. Bibliography.

Embrittlement of Boiler Plate. S. W. PARR and F. G. STRAUB. *Railroad Herald*, 32: 10, September, 1928, pp. 31-37, 4 figs. Outline of investigation; history of study of embrittlement; laboratory investigation; test data on embrittlement.

Embrittlement of Boiler Plates by Chemical Agency. *Iron and Coal Trades Rev. (Lond.)*, 117: 3159, September 14, 1928, p. 367. Results of examination of water-tube boiler, six years old, built and certified for working pressure of 185 pounds per square inch; butt joints suggested but lap joints accepted to save time and extra expense; plate gave every indication of having suffered from chemical embrittlement; prime cause of trouble was punishment that plates received when being riveted. From Tech. Report for 1927, of Brit. Engine, Boiler and Elec. Insurance Co.

Materials for High Temperatures. R. G. C. BATSAN. *Mar. Eng. and Shipg. Age*, 33: 10, October, 1928, pp. 550-551. With special reference to their use in boilers supplying superheated steam; tensile strenght of materials at high temperature obtained by ordinary methods of testing air temperature is misleading; all metals are subject to failure by intercrystalline cracking if temperature is high enough; position as regards materials other than low-carbon steels. Abstracted from *Liverpool Journal of Commerce*.

Strength Testing of Boiler Plate at Elevated Temperature (Festigkeitspruefungen und Kesselblechen bei erhoehten Temperaturen). A. POMP. *Zeit. des Bayerischen Revisions-Vereins (Munich)*, 32: 15 and 16, August 15 and 31, 1928, pp. 192-195 and 210-215, 11 figs. Results of investigation of 14 types of boiler plates of 20 mm. thickness; microscopic and macroscopic analysis; presents diagram showing tensile strength and other mechanical properties. (To be continued.)

Modern Ideas on Boiler-Scale Formation and Its Prevention (Neuzeitige Anschauungen ueber die Kesselsteinbildung und ihre Verhuetung). R. STUMPER. *Waerme (Berlin)*, 51: 31, August 4, 1928, pp. 569-575, 4 figs. This article is review and criticism of paper by R. E. HALL. See reference to original work (published in *Mech. Eng.*, mid.-Nov. issue, 1924), in *Eng. Index*, 1924, p. 76.

Theoretical and Experimental Study of the Formation of Scale in Boilers (Études théoriques et expérimentales sur la formation des incrustations de chaudières). R. STUMPER. *Chimie et Industrie (Paris)*, 20: 1, July, 1928, pp. 10-20, 5 figs. Chemistry of steam boilers; theory and physico-chemical aspects of formation of scale; formation of scale bed. Bibliography.

How to Prevent Boiler Scale and Its Relation to Fuel Conservation. J. J. WELCH. *Steam Coal Buyer*, 10: 2, September, 1928, p. 27. Brief outline of suggestions for practice with locomotives, taken from *New York Central Magazine*.

Results of Tests on Tube Beading (Die Ergebnisse von Versuchen ueber das Einwalzen von Rohren). K. RIES. *Zeit. des Bayerischen Revisions-Vereins (Munich)*, 32: 16 and 17, August 31 and September 15, 1928, pp. 199-204 and 226-231, 18 figs. Aug. 31: Tests were carried out under auspices of Water-Tube Boiler Association at Kaiser-Wilhelm Institute of Iron Research to study phenomena and stress in materials occurring with tube beading. Sept. 15: Results of tests are shown in tables and charts.

The Causes and Prevention of Corrosion in Steam Boilers. C. C. CUSTER. *Nat. Engr.*, 32: 6, June, 1928, pp. 265-268. Chief factor tending to shorten life of boiler is either scale or corrosion; theories regarding corrosion; oxygen in boiler water; electrochemical theory; preventing tube corrosion; embrittlement; protection from weather.

Safe Removal of Caustic Soda from Drums. H. L. KAUFFMAN. *Chem. and Met. Eng.*, 35: 10, October, 1928, p. 633. Description of method used at Parco, Wyo., refinery of Producers and Refiners Corp.; main caustic-soda dissolving tanks are about 6 feet in diameter by 6 feet deep and have capacity of 1300 gallons; each of larger tanks is provided with lines for air, steam, and water, and pumping-out line.

A Particular Case of Tube Damage in High Steaming Water-Tube Boilers (Sur une cause particulière d'avaries de tubes dans les chaudières aquatubulaires à forte vaporisation). E. ALLER. *Associations Françaises de Propriétaires d'Appareils à Vapeur, Bul.*, (Paris), 9: 33, July, 1928, pp. 173-182, 4 figs. Review of causes of damaged tubes in water-tubes in water-tube boilers of various types and description of a particular case.

Boiler Water Analysis Volumetric. *West. Gas*, 4: 9, September, 1928, p. 114. Temporary hardness; magnesia; permanent hardness; determination of dissolved oxygen in water.

A Non-Chemical Method for the Prevention of Scale Accumulation in Boilers, Diesel-Jackets, and Water Circulating Systems in General. A. T. RIDOUT. *Domestic Eng. (Lond.)*, 48: 9, September, 1928, pp. 163-165. Method described is physical system of treating water, as distinct from chemical methods and utilizes colloids; describes briefly properties of true colloids. Colloidal system also effectively deals with presence of oil in boiler feed-water; system can be used to deal with salt feed. Paper read before Inst. Mar. Engrs., previously indexed.

A Non-Chemical Method for the Prevention of Scale Accumulation in Boilers, Diesel-Jackets, and Water-Circulating Systems in General. A. T. RIDOUT.

Inst. Mar. Engrs., Trans. (Lond.), 40: July, 1928, pp. 333-340 and (discussion) 340-350. A physical system of water treatment intended to dispense with chipping hammer and zinc plates in boilers and allow use of water for make-up feed for evaporators to keep them free from all scale formation and in certain circumstances, in Diesel-engine jackets; based on use of true colloids as distinct from so-called "colloids"; acid and galvanic actions in boilers arrested; low upkeep cost, small space for apparatus.

Minerals Affect Feedwater. J. B. ROMER. Power Plant Eng., 32: 17, September 1, 1928, p. 923. Proper treatment depends upon specific conditions; boiling breaks down bicarbonates; non-scale-forming salts may cause corrosion; ideal feedwater is hard to obtain.

Modern Practice in Boiler Feed-Water Purification. G. E. FOXWELL. Gas World (Lond.), 89: 2300, September 1, 1923, pp. 102-106. Author brings before coking industry certain of newer ideas on subject of boiler efficiency as exemplified by modern boiler practice; normal constituents of feedwater; corrosive influence of iron salts; time required for settling of precipitate; Kestner process; influence of oxygen; preventive methods.

Preventing Scale in Diesel-Jackets. A. T. RIDOUT. Gas and Oil Power (Lond.), 23: 276, September 6, 1928, p. 236. Abstract of paper previously indexed from Inst. Mar. Engrs.—Trans. (Lond.)

Treatment of Feed Water. Nat. Elec. Light Assn., Serial Reports, Nos. 278-81, August, 1928, 57 pp., 48 figs. Operation of evaporators under varying range of conditions; summarizes more recent results of research; covers briefly results of past reports; cites new cases of caustic embrittlement and covers experiments on new inhibitives, such as sodium phosphate, tannate and sodium acetate; data in connection with electrolytic processes are presented; statement by International Filter Co. on electroosmosis describes process of purifying water by electrolyzing. Bibliography.

New Weir "Optimum" De-aëerator. Elec. Times (Lond.), 74: 1922, August 23, 1928, p. 267, 2 figs. Ideal to be aimed at is to supply boilers, economizers, and purefeed circulatory system at minimum cost with feedwater completely free from chemical substances in solution or suspension, and entirely non-corrosive; feedwater must be free from dissolved atmospheric gases, particularly oxygen and carbon dioxide; Optimum De-aëerator of G. & M. Weir, Glasgow, described; this provides much simpler means of completely deaërating water with considerable reduction in cost of apparatus and its installation.

Prevention of Locomotive Boiler Corrosion. C. H. KOYL. Ry. and Locomotive Eng., 41: 6, June, 1928, pp. 175-176. Paper presented to Master Boiler Makers' Assn., previously indexed from Boiler Maker, July, 1928.

Treatment of Missouri River Water for Locomotive Use. H. H. RICHARDSON. Indus. and Eng. Chem., 20: 9, September, 1928, pp. 924-925. Statistical re-

sults of operation of nine plants by Missouri Pacific Railroad; in 1927 approximately 794,700 pounds of scale-forming matter from 479,578,000 gallons of water at saving of \$103,311.

Industrial Wastes Affect Plant Water Supply. D. C. CARMICHAEL. *Power Plant Eng.*, 32: 15, August 1, 1928, pp. 813-815, 5 figs. Boiler feedwater taken from polluted stream required various treatments; data from four plants show effect of pollution on feedwater; treating with lime and disposal of resulting sludge; recovery of sulphate of iron. (Concluded.)

Electrolysis Apparatus Producing Hydrogen and Oxygen at High Pressure (*Appareil d'électrolyse produisant directement l'hydrogène et l'oxygène à haute pression*). Génie Civil (Paris), 93: 7, August 18, 1928, pp. 168-170, 2 figs. Describes apparatus of M. NOEGGERATH to electrolyze water and produce hydrogen and oxygen gases at pressure of 150 atmos.; advantage of such electrolyzer.

Chemical Constituents of Water. W. S. MAHLIE. *Domestic Eng.* (Chicago), 124: 9, September 1, 1928, pp. 36, 51-52 and 55. Chart of impurities found in water; usual mineral matters as they are found in water; hardness; alkalinity and acidity; rapid method for calculating chemicals required to soften water; magnesium (volumetric method). Paper presented at Eighth Texas Water Works Short Course.

Preliminary Report on the Chemical Quality of the Surface Waters of North Carolina With Relation to Industrial Use. C. E. RAY, JR., and E. E. RANDOLPH. N. C. Dept. of Conservation and Development, Economic Paper, 61: 73 pp., 6 figs., partly on supp. sheets. Chemical quality of these surface waters is of such a character as to make them unsurpassed for use in industrial processes requiring water exceptionally free from chemical and physical impurities; presents 174 analyses of samples of surface waters and 11 analyses of samples of underground waters.

Differentiation of Organic Matter Contained in Water (*Beitraege zur Differenzierung der organischen Stoffe in Wasser*). K. KEISER. *Technisches Gemeindeblatt* (Berlin), 31: 7, July 5, 1928, pp. 81-86. Report from Hamburg State Institute of Hygiene on experimental study of changes in organic matter of Elbe water brought about by coagulation and chlorination.

How the Turbid Waters of the Tennessee River are Filtered. C. V. SWEARINGEN. *Water Works Eng.*, 81: 8, August 29, 1928, p. 1265. Method of removing turbidity from water supply of Chattanooga; treatment almost entirely by alum; analysis of waters; settling basins; three in number and operate in series; arrangement of filters. Excerpts from paper read before Southeastern Water and Light Association.

Progress in Water Purification. *Eng. World*, 33: 2, August, 1928, pp. 62-64. At Water Purification Division of American Water Works Assn. con-

vention in San Francisco important papers were presented, summaries of which appear herewith; operating experiences with filtration plants; algae control by chlorination.

Water Softening at Piqua. J. M. MONTGOMERY. Pub. Works, 59: 9, September, 1928, pp. 341-345, 7 figs. Two years' operation of plant embodying several unusual features; aerators, chemical feed devices, mixing tanks, clarifier, settling basins, carbonation chambers, filters, chlorine disinfection; overtreatment with lime followed by recarbonation. Paper presented before Ohio Conference on Water Purification.

An Outline of Water Softening. J. F. PIERCE. Am. City, 39: 3, September, 1928, pp. 90-91. Hard water is undesirable and uneconomical for any community, irrespective of size; it is unnecessary evil, and one that can be easily remedied; geographical distribution of hardness; softening by zeolite method; applicability of zeolite process to small-community softening problems.

Zeolite Softening of Lime-Treated Water at Columbus, Ohio, Water Softening and Purification Works. C. P. HOOVER, V. L. HANSLEY, and C. Q. SHEELY. Indus. and Eng. Chem., 20: 10, October, 1928, pp. 1102-1105, 4 figs. Purpose of this investigation was to determine whether or not it would be better and more economical for city of Columbus, Ohio, to continue to soften its public water supply with lime and soda ash, or to use lime treatment in connection with Zeolite as a substitute for soda-ash treatment.

Water Softening for Municipalities. E. BARTOW. Am. City, 39: 4, October, 1928, pp. 131-132. Consideration of few of modern up-to-date softening plants, including Columbus, O., Oklahoma City, Springfield, Ill., Decatur, Ill., plants in Iowa, Hinsdale, Ill., and railroad plants. From paper presented before Iowa Academy of Science.

Construction and Operation of Water Works (Bau und Betrieb von Wasserwerken). H. EIGENBRODT. Bauingenieur (Berlin), 9: 40, October 5, 1928, pp. 721-724, 5 figs. Principles of water purification by slow and rapid filtration, treatment with ozone, chlorination, etc. (Continuation of Serial.)

Electro-Osmotic Purification of Water (Electro-Osmotische Wasserreinigung), A. H. W. ATEN. Chemisch Weekblad (Amsterdam), 25: 1281, April 14, 1928, pp. 211-219, 5 figs. Apparatus manufactured by Siemens Electro-Osmosis Co. of Berlin for purification of water is described, and results are given of tests carried out.

Filtering and Filter Washing in Open Deferrization Plants (Der Filter und Spuervorgang in offenen Enteisungsanlagen). G. THIEM. Gas- und Wasserfach (Muenchen), 71: 35, September 1, 1928, pp. 852-854, 4 figs. Theory and practice of use of fine and coarse filters, filter washing, etc. in deferrization plants for large water supplies from underground sources.

Boiler-Feed Water. ELLIOTT, A. G. *Pacific Mar. Rev.*, 25: 20-2; *J. Am. Water Works Assn.*, 19: 634 (1928). *Chem. Abstracts*, 22: 20, 3941, October 20, 1928. Methods of testing for acidity and alkalinity are given and many analyses are made.—D. K. French.

Boiler-Feed Water Treatment from a Manufacturer's Viewpoint. ROMER, J. B. *Proc. Am. Ry. Eng. Assn.*, 29: 1032-7 (1928). *Chem. Abstracts*, 22: 18, 3474, September 20, 1928. A general review of boiler-feed water impurities and their effect.—R. C. Bardwell.

Boiler-Feed Water Treatment in the Southwest. HOOTS, PAUL F. *Elec. World*, 91: 1340 (1928). *Chem. Abstracts*, 22: 16, 3009 (1928). A detailed statistical report.—C. G. F.

Boiler-Scale Formation and Feed-Water Purification. FREYTAG, HANNS. *Teer u. Bitumen*, 26: 399-403, 1928. *Chem. Abstracts*, 22: 19, 3717, October 10, 1928. A review.—F. S. Granger.

Carbonate and Sulfate Waters: Their Relative Influence on the Operation and Maintenance of Boilers and their Comparative Costs of Purification. Comm. Rept. *Proc. Am. Ry. Eng. Assn.*, 29: 156-7, 1928; *Chem. Abstracts*, 22: 18, 3474, September 20, 1928. Cost per pound for treatment varies from 0.44 c. for CaCO_3 to 1.66 c. for MgSO_4 . Cost in blow-down water for Na_2SO_4 averages 4 c. per pound and soft sludge and suspended matter about 1 c. per pound unless blown out by necessity for reducing alkali concentration.—R. C. Bardwell.

Causes of Boiler Pitting and Means of Prevention in Neutral and Alkaline Waters. KOHL, C. H. *Proc. Am. Ry. Eng. Assn.*, 29: 131-3, 1928. *Chemical Abstracts*, 22: 18, 3474, September 20, 1928. General review.—R. C. Bardwell.

Circulating Steam in the Coffin Feedwater Heater. Anon. *Railway Age*, 84: 24A, 1420-40, 1928. *Chem. Abstracts*, 22: 18, 3474, September 20, 1928. Diagram and method are shown for installing and operating a feed-water heater on a locomotive.—R. C. Bardwell.

Cost of Blow-Down of Locomotive Boilers. TANNER, R. A. *Proc. Am. Ry. Eng. Assn.*, 29: 152-5, 1928. *Chem. Abstracts*, 22: 18, 3474, September 20, 1928. Foaming point must be determined for individual district and conditions after which amount of blow-down and cost can be calculated. Formula and chart are included.—R. C. Bardwell.

Deconcentrating Treatment of Boiler Water. GRIFFIN, H. L. *Power Plant Eng.*, 32: 869-70, 1928. *Chem. Abstracts*, 22: 18, 3473, September 20, 1928. Continuous blow-down is made economical by utilizing heat of blow-down water to heat fresh feed-water. Regulators make it impossible for blow-down

water to leave the deconcentrator before its temperature has reached 65°F.
—*S. D. Poarch.*

Embrittlement of Steel. CHRISTIE, ALEXANDER G. et al. *Proc. Am. Ry. Eng. Assn.*, 29: 1062-74, 1928. *Chemical Abstracts*, 22: 18, 3475, September 20, 1928. A general review of controversy on the effect of various mineral constituents in boiler-feed water on the embrittlement of boiler metal indicates a need for further study and research.—*R. C. Bardwell.*

Feedwater Heaters Reduce Pitting. KOYL, C. H. *Railway Age*, 84: 629-30, 1928. *Chemical Abstracts*, 22: 18, 3474, September 20, 1928. Weekly examination, over a period of thirty months, of flues in locomotive boiler equipped with open-type feed-water heater operating between Sioux City, Ia., and Mitchell, S. D., on the C. M. & St. P. Ry., developed a practical absence of pitting, while similar locomotives not so equipped pitted badly. The test indicates that elimination of O by open-type locomotive feed-water heater will greatly retard boiler corrosion in water high in alkali salts, which otherwise pit, although NaOH is present. In addition, the fuel saving averaged \$1000 per year.—*R. C. Bardwell.*

Feedwater Treatment for High-Pressure Boilers. RODT, V. Z. *Bayerischen Revisions-Ver.*, 31: 1, 5-6; *J. Am. Water Works Assn.*, 19: 229, 1928. *Chem. Abstracts*, 22: 20, 3941, October 20, 1928. To avoid concentrations of soluble salts which cannot be removed chemically, evaporators are recommended.—*D. K. French.*

Foaming of Locomotive Boilers with Special Reference to the Influence of Suspended Matter on Foaming and Cost of Blow-Down. *Comm. Rept. Proc. Am. Ry. Eng. Assn.*, 29: 143-52, 1928; *Chem. Abstracts*, 22: 18, 3474, September 20, 1928. General review, with charts and tables, indicates that foaming in locomotive boilers will vary with type, character, and amount of suspended solids, and also with the type of work being handled by the locomotive.—*R. C. Bardwell.*

Industrial Wastes Affect Plant Water Supply. CARMICHAEL, D. C. *Power Plant Engineering*, 32: 711-4, 813-5, 1928. *Chem. Abstracts*, 22: 17, 3248, September 10, 1928. A study of a stream polluted with wastes from an iron mill. The effects on feed water for boilers and cooling water for condensers are noted. Treatment of plant water is outlined. Neutralization of acid wastes from iron mills with lime and recovery of FeSO_4 are suggested as methods to dispose of trouble.—*S. D. Poarch.*

New Cooling Apparatus Cracks off Scale. Anon. *Oil & Gas J.*, 26: 51, 76, 1928. *Chem. Abstracts*, 22: 15, 2802, 1928. A cooler or condenser developed by the Griscom-Russell Co. consists of a series of Admiralty metal tubes set with an initial curvature into cast iron headers. Scale formed on the tubes by the evaporation of the cooling water is automatically cracked off if the flow of hot liquid through the tubes is interrupted, causing them to return to

their initial curvature. The same principle is applied to evaporators for distilling pure boiler feed water from hard, dirty, or salt water.—*M. B. Hart.*

New Water Supply Facilities Effect Economies on the Southern. Anon. *Railway Age*, 84: 1329-32, 1928. *Chem. Abstracts*, 22: 18, 3474, September 20, 1928. The Southern Ry. recently completed extensive improvements to the Yadkin River plant at their Spencer, N. C., Terminal. A 2,500,000-gallon sedimentation basin is provided with facilities for alum and dry sodium aluminate treatment. Present consumption averages 1.3 m.g.d. Automatic electrical control is provided for raw water and transfer pumps.—*R. C. Bardwell.*

Modern Boiler Problems. CHRISTIE, A. G. *Power*, 67: 946-9, 1928. *Chem. Abstracts*, 22: 16, 3009, 1928. A discussion.—*D. B. Dill.*

Preliminary Purification of Boiler-Feed Water. GUTH, J. *Bull. assns. françaises propriétaires appareils à vapeur*, 28: 136-46, 1927; *J. Am. Water Works Assn.*, 19: 230, 1928. *Chem. Abstracts*, 22: 20, 3941, October 20, 1928. A discussion of water treatment before it enters the boilers.—*D. K. French.*

Pretreatment of Boiler-Feed Water. GUTH, J. *Bull. assns. françaises propriétaires appareils à vapeur*, 8: 299-315; *J. Am. Water Works Assn.*, 19: 635, 1928. *Chem. Abstracts*, 22: 20, 3941, October 20, 1928. A theoretical treatment of physics, chemical purification, and the use of soda and heat.—*D. K. French.*

Pretreatment of Boiler-Feed Water. KNOWLES, C. R. *Proc. Am. Ry. Eng. Assn.*, 29: 1045-51, 1928. *Chem. Abstracts*, 22: 18, 3474, September 20, 1928. Review of lime-soda and lime-soda-zeolite methods.—*R. C. B.*

Preventing and Removing Incrustation in Boilers. BILLWILLER, J. *Brit.* 281,361, August 25, 1926. See *Can.* 281,216 (*C.A.*, 22: 3010). *Chemical Abstracts*, 22: 18, 3477, September 20, 1928.

Preventing Incrustation in Boilers. Soc. Anon. Subox. *Brit.* 281,598, December 4, 1926. *Chemical Abstracts*, 22: 18, 3477, September 20, 1928. Resin "in the hydrated state," such as is obtained by treating colophony in the presence of a solvent with an alkaline substance and then with an acid substance, is used, with or without other substances such as a gum, tannin, or dextrin.

The Prevention of Boiler Pitting in Neutral and Alkaline Waters by the Exclusion of Dissolved Oxygen from the Feed-Water. KOYL, C. H. *Proc. Am. Ry. Eng. Assn.*, 29: 133-5, 1928. *Chem. Abstracts*, 22: 18, 3474, September 20, 1928. Operation of locomotives equipped with an open feed-water heater in the alkali water district on the C. M. & St. P. Ry., during the past 3 years has shown good results in reduction of pitting and corrosion as

compared with similar engines in similar service not so equipped. The average removal of dissolved O was 60 per cent. Inaction of the remaining O is accounted for by the surge of water in locomotive boiler. Details and regularity of operation are important.—*R. C. Bardwell.*

Purification of Water for Boiler-Feed Purposes. DUGGAN, T. R. J. Eng. Inst. Canada, 10: 8, 379-85; J. Am. Water Works Assocn., 19: 230, 1928. Chem. Abstracts, 22: 20, 3941, October 20, 1928. A review.—*D. K. French.*

System for Heating, Deaerating, and Evaporating Water. GIBSON, GEORGE H. (to Cochrane Corp.). U. S. 1,677,890, July 24. Chemical Abstracts, 22: 18, 3477, September 20, 1928. Apparatus is described suitable for use in preparing boiler-feed water from condenser condensate and raw make-up water with steam at high and low pressures.

The Treatment of Water for Locomotives from the Standpoint of Chemical Engineers. BARR, WM. Proc. Am. Ry. Eng. Assocn., 29: 1025-31, 1928; cf. C. A., 22: 834; Chem. Abstracts, 22: 18, 3474, September 20, 1928. General discussion of railway water treatment problems including compounds, lime-soda and zeolite methods.—*R. C. Bardwell.*

Use of Exchange-Silicate (Zeolite) Water Softeners in Railroad Practice. BAXTER, GEORGE L. Ind. Eng. Chem., 20: 755-8, 1928. Chem. Abstracts, 22: 18, 3473, September 20, 1928. Exchange-silicate (zeolite) treatment at certain points on the Southern Pacific Lines has been found less expensive than treatment with lime and soda ash and has resulted in more satisfactory operation of stationary and locomotive boilers.—*J. A. Kennedy.*

The Value of Boiler Water Treatment to the Mechanical Department. RAPS, J. F. Proc. Am. Ry. Eng. Assocn., 29: 1022-4, 1928. Chem. Abstracts, 22: 18, 3474, September 20, 1928. Review of improvements effected on the Ill. Central R. R., by water treatment.—*R. C. Bardwell.*

NEW BOOKS

Surface Water Supply of the United States, 1924. Part 1. North Atlantic Slope Drainage Basins. NATHAN C. GROVER, C. H. PIERCE, A. W. HARRINGTON, O. W. HARTWELL, and A. H. HORTON. Geological Survey Water Supply Paper 581. Investigation of water resources in this country by the Geological Survey has consisted primarily in measuring the flow of streams and studying the factors affecting that flow. Results of this work are published annually in 12 parts, each covering an area whose boundaries correspond with natural drainage features. This volume gives the data collected for the year ending September 1924 at gaging stations in the area numbered 1 and designated as the North Atlantic Slope Basins. The tabular records at each gaging station include discharge measurements, daily discharge in second-feet, and monthly discharge.—*Arthur P. Miller.*

Surface Water Supply of United States, 1924. Part 10. Great Basin. NATHAN C. GROVER, A. B. PURTON, H. D. MCGLASHAN, F. F. HENSHAW, C. G. PAULSEN, and ROBERT FOLLANSBEE, district engineers, 1928. Geological Survey Water-supply paper 590.

Surface Water Supply of United States, 1924. Part 11. Pacific Slope Basins in California. NATHAN C. GROVER, H. D. MCGLASHAN and F. F. HENSHAW, district engineers. 1928. Geological Survey Water-supply paper 591.

The Simple Goitre. ROBERT MCCARRISON. pp. xi + 106. With 143 illustrations. 1928. London: Baillière, Tindall & Cox. 10s. 6d. net. Bull. of Hygiene, October, 1928. 3: 907. Among other discussion of only general interest to water engineers, this author brings out that it has been possible to produce in both animals and in man simple goitre by feeding infected material such as water contaminated with sewage. Goitre has been seen to disappear from an endemic area after a new and pure water supply was provided even though the iodine content of the new and old supplies were relatively the same. The main conclusion from these observations is that the provision of adequate iodine in water and food may often prevent goitre.—Arthur P. Miller.

Ninth Annual Report of the Scottish Board of Health, 1927. 391 pp. 1928. Edinburgh. 6s.6d. Bull. of Hygiene 3: 10, 904, October, 1928.—Arthur P. Miller.

Biologie der Trink- und Brauchwasseranlagen. By H. BEGER and E. BEGER. 104 pp., 46 text figures; Jena, 1928.

The results of numerous investigations of water works, the abundant material of the Preussische Landesanstalt für Wasser-, Boden- und Lufthygiene, and material supplied by many well drillers have furnished the basis of the present synopsis of the organisms commonly found in different types of water supplies and their significance in helping to judge the quality of water for domestic or industrial use.

In addition to a series of brief, but instructive, notes on sampling and the preservation of material, the bulletin is divided into two parts; the first half describes many of the microscopic forms and sediments (frequently illustrated) found in water supplies and discusses their indicator value, and the second half lists the organisms comprising the characteristic population of different types of supply.

Among the indicator organisms, the following are mentioned:

(1) Iron depositing organisms (*Crenothrix polyspora*, *Leptothrix ochracea*, *Gallionella ferruginea*, *Trachelomonas hispida*, *Anthophysa vegetans*) found in wells and mains are reliable indicators of iron and manganese and of the unsuitability of the water for laundries, tanneries, paper and photographic plate manufacture, etc.

(2) Sulfur bacteria, in the strict sense, oxidize hydrogen sulfide to sulfur as a source of energy and assimilate CO_2 , requiring no organic food. They are positive indicators of H_2S and, except in sulfur springs, indicate septic action.

True sulfur bacteria are classified into colorless and red forms; the latter require well-lighted strong H_2S waters and are restricted to sulfur springs (e.g. *Chromatium okenii*). The colorless ones (*Beggiatoa alba*, *Thiothrix nivea*) are found in wells and service mains, though *Thiothrix* in general prefers open flowing water.

(3) Lime depositing forms. A series of higher plants deposit $CaCO_3$ on their leaves and stems (e.g. *Potamogeton*, *Ranunculus*, *Myriophyllum*, *Ceratophyllum*, *Helodea*); some mosses and even some algae (*Vaucheria*, *Scytonema*, *Schizothrix*, *Tolypothrix*, *Rivularia*, *Gloeocapsa*, *Gloeotheca*) have this ability. Bacteria, by producing ammonia from proteins or nitrates cause the deposition of $CaCO_3$, and crystals of this substance are found in bottom mud from wells.

(4) Sodium chloride indicators. In addition to the higher plants characteristic of salt marshes, etc., many of the diatoms are salt indicators. Kolbe has classified them as Euhalobic (marine forms, 3 to 4 per cent salt), mesohalobic (brackish, 0.5 to 2 per cent salt) and Oligohalobic; the last group is further divided into halophilic, indifferent and halophobic forms. Examples are given.

(5) Saprobic forms indicating the presence of organic matter; these forms range from the polysaprobic types in heavily polluted water, through the mesosaprobic, to the oligosaprobic of clean water. Appearance of the first two gives a warning regarding potability (e.g. *Sphaerotilus natans*, *Zoogloea ramigera*, *Spirillum undula*, *Euglena viridis*, etc.).

(6) Clean water indicators. While theoretically a good drinking water should be free from living forms, this is rarely the case excepting for some purification plant effluents. Thus harmless forms of small crustaceans, diatoms, desmids and algae are common inhabitants of clean waters.

(7) Fungi all require organic food material and their presence indicates organic decay (e.g. *Sphaerotilus*, *Mucor*, *Penicillium*, *Aspergillus*, *Saprolegnia*, *Fusarium*, etc.).

(8) Mosses, ferns, and trees have in some cases a direct bearing on water supplies. Various other organisms (nematode, tubificid and lumbricid worms, sponges, etc.) as well as sediments (starch granules, plant remains, fragments of insects, etc.) are instructive in judging the quality of a water. Certain distinctly pathogenic forms may be encountered; e.g. eggs of parasitic worms (*Ascaris lumbricoides*, *Oxyuris vermicularius*, *Trichocephalus dispar*, *Anchylostoma duodenalis*), in addition to pathogenic bacteria and the indicator organism, *B. coli*.

In the second half of the bulletin are listed organisms which have been found in different types of supplies; for example, in all wells, *Trinema*, *Euglypha*, *Diiflugia*, *Melanomma* threads, *Fusarium* spores and some diatoms are apt to occur, other inhabitants being more dependent upon the character and construction of the well. Similarly cisterns, reservoirs, etc. each have a characteristic flora and fauna, varying however with the cleanliness of the water or of the storage basin.

A bibliography of 161 references furnishes a valuable synopsis of the more recent literature on the biology of water supplies.—S. L. Neave.